Issued with Army Orders for December, 1925

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GLOSSARY OF TERMS

Abatis.—An obstacle formed of trees or branches of trees picketed to the ground, with their points towards the enemy.

Batter.—The slope of the face of any earthen, stone or masonry structure which is not vertical.

Baulk.—A timber beam, or road-bearer of a military bridge.

Bay.—The distance bridged by one set of baulks or road-bearers (*see Fire bay*).

Berm.—The distance between the edge of an excavation and the mound formed of the excavated earth—in a defence work.

Bight.—The portion of a rope used double when the ends are not available.

Bivouac.—A camp without tents or huts.

Borrow-pit.—An excavation from which earth is taken for a particular purpose, *e.g.*, building a breastwork.

Breastwork.—A defence work of which the greater portion of its height is above ground level.

Butt.—The thick end of a spar.

Calibre.—Diameter of the bore of a gun in inches not counting the depth of the grooves.

Camouflage.—Any artificial means employed to deceive the enemy's visual or photographic observation from the ground or from the air.

Chess.—A specially prepared plank which forms the decking of a pontoon bridge.

Cleat.—A small piece of wood fixed to another to form a support or stop against movement.

Command.—The vertical height of the crest of a work above the ground level or above the crest of a neighbouring work.

Communications.—Roads, railways, waterways and air routes.

Consolidation.—Making captured ground secure against attack by careful organization of the troops and by provision of protection.

Cover.—Concealment from view or protection from enemy projectiles.

Crest.—The highest point of a parapet, usually the intersection of the superior with the interior slope.

Dead ground (or *water*).—Ground or water over which observed or unobserved fire cannot be brought to bear.

Dead load.—A stationary load which is applied continuously to a structure.

Defended post.—A group of trenches or organized shell holes, &c., allotted for defence by a section of infantry or corresponding unit.

Defended locality.—An area of ground organized for defence by a definite unit, such as a platoon, company, or battalion, and consisting of a system of mutually supporting defended posts, sited so as to cover all ground to the front, flanks and rear of the locality with fire.

Defensive system.—Works which comprise the complete organization of defence.

Defilade.—The adjustment of the levels of the crest and interior of a work to secure cover for the defenders.

Depots.—'General establishments' in which personnel animals, supplies, stores or ammunitior are held and dealt with iu bulk. They are controlled by G.H.Q.

Detonator.—A small amount of very high explosive in a container which can be fired by ignition to explode a charge.

Direct laying.—The method of laying a gun by looking at the target over or through the sights.

Dog.—A bar of iron of which the ends are pointed and bent inwards at right angles—used for fastening heavy timbers together.

Drift bolt.—A specially made long iron spike, up to 30 inches in length and 1 inch in diameter, used for securing heavy timbers together, particularly members of squared timber trestles.

Dug-out.—An underground chamber or passage.

Dumps.—Small collections of supplies, stores or ammunition accumulated temporarily for some particular purpose.

Embrasure.—The aperture in the wall of an emplacement through which a gun fires.

Enfilade fire.—Fire which sweeps the position from a flank.

Field of fire.—An area of ground which any unit or weapon can cover with fire.

Fire bay.—A length of trench from which it is intended to deliver rifle fire.

Forward (or covering) zone.—That portion of a defensive system, in position warfare, which is in advance of the main zone.

Frame.—A structure used in underground work consisting of a top sill, bottom sill and two legs.

Frontage.—The extent of ground covered laterally by a body of troops.

Frontal fire.—Fire, the line of which is perpendicular to the front of the target.

Gap.—With reference to bridging, that portion of a river, canal, sunken road, ditch or other obstacle, over which a bridge is made.

Glacis.—The ground round a work within close rifle fire, sometimes formed artificially. A term used to describe an even natural slope.

Gradient.—A slope represented by a fraction, *e.g.*, 1/30 represents a rise or fall of one unit measured vertically for every 30 units measured horizontally.

Grazing fire.—Fire which is parallel or nearly so to the surface of the ground.

Groundsill.—The bottom member of a frame or sett used in work underground.

Headcover.—Protection against frontal or oblique fire for the heads of men when firing over a parapet.

Helve.—Handle of pick-axe or felling-axe.

High angle fire.—Fire delivered from guns and howitzers at angles exceeding 25°.

Intelligence post.—A post occupied by unit, brigade, divisional or corps observers, for watching the enemy and ground on their front.

Keep.—A work within the system of defence of a defended locality, and distinct from it. Commanding a field of fire within the outer defences with a view to assisting in their recapture in case of need.

Lead.—Pronounced Leed. Any wire used to convey an electric current.

Live load.—A load which is suddenly applied to a structure or part of a structure with an impact producing stresses in excess of those due to its weight when at rest (*see Dead load*).

Look-out post (L.O.P.).—A post from which the progress of the battle can be watched.

Main zone.—That portion of a defensive system, in position warfare, in which the commander decides to fight out the battle, and break the enemy's attack.

Oblique fire.—Fire, the line of which is inclined to the front of the target.

Observation post.—A position whence the fire of a battery or a smaller unit of artillery is observed, corrected and controlled.

Overhead cover.—Protection by means of a roof, against splinters, shells or bombs.

Parados.—A bank of earth constructed to give protection against reverse fire, and the back burst of high explosive shells.

Parks.—Collections of personnel, animals, supplies, stores or ammunition placed by G.H.Q. at the disposal of subordinate commanders. Administrative records are kept of receipts and issues.

Primer (except artillery).—A specially prepared nature of high explosive which acts as the medium of detonation between the detonator and the demolition charge.

Profile.—The outline of the section of a work at right angles to the crest line.

Rear position.—A separate defensive system some miles in rear of the leading system, which can be occupied in the event of the leading system being captured by the enemy.

Part III—**Accommodation.**—Is devoted to the construction in camp or trenches of all shelters and dug-outs, including cooking and sanitary accessories.

Part IV—**Communications.**—Deals with tracks, roads and tramways, and the information is confined to that which would be required for work in the more forward areas.

Part V—**Demolitions.**—Includes the use of the common explosives supplied for use in the field. Accidents have occurred in the past which have been due to ignorance and the mistaken idea that any work which involves the use of explosives is the prerogative of experts. All ranks must be trained in handling the many and various explosives used by all arms.

Further information on the above subjects can be found in Military Engineering, Vols. I to IX.

Night work.—No special notes have been given as regards work at night. It must be recognized that work at night in the forward area is the rule and not the exception, and that both officers and men require the most careful training, to ensure that loss of time and waste of labour are reduced to a minimum. When, therefore, men have been taught the use of tools and how to file on to their work, the majority of the training should be done at night.

PART I.—FIELD FORTIFICATION

CHAPTER I

GENERAL PRINCIPLES OF FIELD FORTIFICATION

1. *Definitions.*

1. **Field fortification** includes all measures taken to strengthen a position by means of works constructed in the face of the enemy, or in anticipation of his immediate approach to the scene of action.

These works are called field works or field defences.

2. The main objects of field defences are :—

i. To develop to the utmost the power and effect of the defender's weapons. This will normally be effected by putting the defender in a position whence he can use them freely, and where the attacker will be exposed to them for as long a time as possible ;

ii. To restrict to the greatest possible extent the effect of the attacker's weapons. This is normally effected by protecting the defender from them, thereby reducing casualties ;

with the general effect that, by skilful use of field defences combined with fire effect, a commander may be able to reduce the strength of his force in actual combat with the enemy to a minimum ; and thus to form a reserve for the decisive action either in his own sector or for transfer to some other part of the theatre of war. The stronger the defences, and the more work put into their construction, the greater will be the economy of strength in holding them.

3. Although field defences presuppose a defensive attitude locally, they play a most important part in all offensive operations, and in this connection they must be most carefully studied.

Whether on the offensive or defensive, it must be remembered that the guiding principle remains the same, namely, that the defences are to be constructed to conform with the tactical plan of operations and that they are only a means to an end and not an end in themselves.

4. The following considerations should be borne in mind when preparing field defences :—

i. Work should proceed on a definite programme and should be undertaken by stages, so arranged that in case of interruption what has been done will be of value.

ii. Surprise is of paramount importance ; concealment must therefore be considered from the outset. It is useless to conceal M.G. emplacements or the limits of defended posts by camouflage, dummy works, &c., *after* the enemy has had an opportunity of photographing them.

iii. Economy of labour. Fighting troops will have to be employed, but parties must be kept at a minimum.

iv. Value of task work.

v. Object of work to be kept in view.

vi. Importance of continuity of control, since the handing over of work in progress from one unit to another causes loss of efficiency.

vii. Importance of engineer reconnaissance and of early anticipation of requirements in material and labour.

viii. Comparative efficiency of labour under varying conditions (*i.e.*, night work and day work, long and short spells, wearing of box respirators, &c.).

5. Field defences are of two classes :—

Hasty.
Deliberate.

6. **Hasty defences** are made actually on the battlefield, by the attacking troops, to secure the ground they have taken (*see* Sec. 70, 7, F.S.R., Vol. II, 1924) ; or by the defender to hold up the progress of the enemy, while fresh dispositions of troops are being made in rear.

The design of hasty defences follows generally the rules laid down for deliberate works, but the conditions under which they are made do not allow the same accuracy of line, dimensions, &c., to be maintained.

The aim of a commander who has been ordered to make good the ground he holds, is to get his men under cover in the quickest possible way.

In an encounter battle the tools available will be such entrenching tools as it may be possible to bring up during the night. The amount of digging which can be done is comparatively small, so that to get the protection required every use must be made of the cover which actually exists on the battlefield.

This cover may consist of hedges, walls, buildings, banks, sunken roads, railway embankments and cuttings, woods and shell-holes. All of these are easily convertible into strong defences if intelligently treated; they have all played important parts in battles, and it has been proved that troops well trained in adapting natural cover to defence are extremely difficult to eject when once they have dug themselves in.

The works are described in detail in Chapters VI, VII, VIII and IX.

7. **Deliberate field defences.**—Under this head come all defences which are not included under hasty defences, but which are not so imposing as to be called permanent fortifications. The only considerations which limit their scope are :—

i. The time, material and labour available.

ii. The industry and skill of that labour.

iii. The ability of the enemy to interfere with their construction.

Deliberate field defences would be employed in :—

i. The gradual development of a defensive system, when once the opportunity of manœuvre has ceased.

ii. The later stages of consolidating an objective taken during the period of position warfare.

iii. The preparation of rear defensive systems.

They are described in detail in Chapters V, VI, VII, VIII and IX.

2. *Effect of modern war equipment on the design of field fortifications.*

In order that field fortifications may be designed to the best advantage, it is necessary to study the characteristics of the various forms of war equipment which may be used against them.

The power and nature of the equipment employed affect the design of field fortifications in two ways:—

i. The range, rate of fire and radius of activity influence the siting of the works and obstacles.

ii. Their penetration, searching power and destructive effect govern the amount, disposition and nature of the protection necessary for security.

3. *Rifles, light automatics and machine guns.*

1. **Rifle fire.**—Modern military rifles are sighted to about 2,800 yards. Their maximum range may be taken as about 3,700 yards. The slope of descent of the bullet varies from about 1/120 at 600 yards and 1/30 at 1,100 yards, to 1/4 at 2,200 yards.

The following table gives the maximum penetration of a single pointed rifle bullet into various materials. It does not allow for a number of bullets hitting on or near the same spot. To be bullet-proof under service conditions, the thickness of all materials, such as earth or shingle, must be about 50 per cent. greater than that given in the table:—

Material.	Maximum penetration.	Remarks.
	Inches.	
Steel plate, ordinary mild or wrought iron	$\frac{3}{4}$	
Shingle	6	Not larger than 1-inch ring gauge.
Coal, hard	9	Between 1-inch boards.
Coal, small kitchen ...	15	Between 1-inch boards.
Brickwork, cement mortar	9	
Brickwork, lime mortar ...	14	With mud bricks—18 inches.
Chalk	15	
Sand, confined between boards, or in sandbags	18	With dry sea or desert sand this may be reduced to 12 inches.
Sand, loose	30	
Earth, free from stones (unrammed)	40	Ramming earth reduces its resisting power.
Sawn timber:—		
Hardwood, *e.g.*, oak ...	38	In timber, the penetration is much less in round logs than in scantling, owing to the deflection of the bullet, but care must be taken to fill the interstices.
Softwood, *e.g.*, fir ...	56	
Green timber:—		
Logs 12 inches diameter and over	24	
Poles 4½ to 6 inches in diameter	36	
Clay	60	Varies greatly. This is maximum for greasy clay.
Dry turf or peat	80	
Snow...	—	Varies greatly. 3 feet of rammed frozen snow, well consolidated with water, will stop a bullet, but the power of resistance will decrease as the temperature rises. Soft snow unrammed has little power of resistance.

2. **Light automatic and machine-gun fire** is a concentrated form of rifle fire, capable of being directed with great accuracy on to a small area. It can also be traversed when a less concentrated stream of bullets will be delivered against a target, such as a trench or a line of troops in the open. In this way it can be used to support an attack by keeping down the heads of firers in a trench. Machine guns can be used to fire indirect, that is from behind cover, the fire being directed generally with the aid of maps.

The machine-gun attack from aeroplanes will take the form of direct fire at point blank range, and the rule of slope of trajectory will not apply in this case.

At ranges beyond 300 yards the penetration of light automatic and machine-gun fire may be taken to be equal to that of concentrated rifle fire. At distances under 300 yards, owing to the cumulative and shattering effect produced by a number of shots striking rapidly in succession over a small area, penetration is effected more rapidly and with fewer number of rounds than by rifle fire.

4. Artillery.

1. The **natures of artillery,** any or all of which may accompany an army in the field, consist of guns, howitzers and mortars.

Details of guns and howitzers and their classification are as follows :—

Classification.	GUNS.					HOWITZERS.				MORTARS.	
	Nature.	Maximum range.		Maximum weight on any axle when travelling.		Nature.	Maximum range.	Maximum weight on any axle when travelling.		Nature.	Maximum range.
		H.E.	Shrapnel.								
				Tons	Cwt.			Tons	Cwt.		
A.A. ARTILLERY	3-in. 20 cwt.	—	18,000 ft. at 4,500 yds.	Peerless lorry and trailer, 7 Travelling platform, 6	16¾ 6½	—	—	—		3-in. 4-in.	1,950 940
LIGHT ARTILLERY—		Yards.	Yards.				Yards.				
A. Pack Artillery ...	2·75-in.	5,800	5,600	—	—	3·7-in.	5,900	—	—	6-in.	1,800
B. Horse Artillery ...	13-pdr.	8,600	6,400		19	—	—	—	—		
C. Field Artillery ...	18-pdr.	10,600	6,500	1	4	4·5-in.	7,000	1	6		
MEDIUM ARTILLERY— Horse-drawn and tractor-drawn	60-pdr.	16,100	15,100	4	3	6-in.	10,800	3	12½		
HEAVY ARTILLERY— Tractor-drawn or railway mounting.	6-in. Mk. XIX.	19,000	15,800	10	0	8-in.	12,000	8	18		
	6-in. Mk. VII.	—	—	—	—	9·2-in.	13,900 (super-charge)	4 (on rear axle of "carriage and limber transporting body and cradle")	3		
SUPER HEAVY ARTILLERY— Tractor-drawn or railway mounting.	9·2-in.	25,000	24,200	17	0	12-in. (Mk. IV Road)	14,300	9 On rear axle of "wagon transporting cradle")	4½		
Railway mounting ...	—	—	—	—		12-in. Mk.III & V.	14,300	19	10		
" " ...	14-in Mk. VI.	34,400	—	17·29 tons		18-in. Mk. I.	22,250	17	10		

Note.—The figures given for maximum range apply to new guns and howitzers under normal weather conditions. Wear of guns and howitzers and adverse weather conditions will considerably affect these ranges.

2. The principal characteristics of "**guns**" are their high muzzle velocity, which permits them to fire at long ranges; the flatness of the trajectory of their shells which, when using shrapnel, gives deep searching effect; and, in the case of light artillery, the rapidity of their fire.

Pack guns (2·75-in.) are peculiarly suited to broken, hilly country and are comparatively easily concealed on the move. They are suitable for close support of infantry.

Horse Artillery guns (13-pr.) are a very mobile form of artillery and are primarily intended for use with cavalry. They may, however, also be employed to support the combined action of other arms, similarly to field guns.

Field guns (18-pr.) are heavier than horse artillery and have greater shell power; they form the bulk of the artillery with a force. Their principal task is to assist the infantry to close with the enemy. They are specially suited for covering fire, repelling attacks in the open and raking communications, and for wire cutting when howitzers and mortars are not available. They are the most effective artillery anti-tank defence weapon.

Anti-aircraft guns (3-in. 20-cwt.) are less mobile than field artillery. They are provided for protection against enemy air activity and may, in an emergency, be used against tanks.

Medium guns (60-pr.) are employed in counter-battery work, for raking communications and covering fire beyond the range of light guns.

Heavy (6-in.) **and super heavy guns** (9·2-in. and upwards) are used for raking distant communications and for shelling camps, dumps, railway stations, &c., beyond the range of other artillery, and for long range counter-battery work. 6-in. guns are especially useful against balloons.

3. The principal characteristics of "**howitzers**" are high trajectory, comparatively low muzzle velocity and great shell power.

As compared with guns, they can be placed in positions offering greater opportunity for concealment and cover from shell fire.

They are especially adapted for the destruction of strong works and for engaging entrenched troops and batteries. With instantaneous fuzes, they are very effective against troops in the open and for harassing fire.

Howitzers have less range than guns of a similar shell power but are more mobile and more easily concealed.

Pack howitzers (3·7-in.) are particularly useful for the close support of infantry and also for anti-tank defence.

Field howitzers (4·5-in.) are employed for covering fire in attack and defence, for wire cutting, for smoke screens, for bombarding weaker defences and ill-protected batteries and for counter-battery work in mobile warfare.

Medium howitzers (6-in.) are used for covering fire, for wire-cutting and the destruction of defences and the neutralization of hostile batteries. They are particularly suitable for counter-battery work in mobile warfare.

Heavy (8-in. and 9·2-in.) **and super heavy howitzers** (12-in. and upwards) are employed in counter-battery work against batteries provided with good cover and in the destruction of strong defences.

4. The principal characteristic of "**mortars**" is their power of developing destructive and accurate fire at short ranges.

Their utility is restricted not only by their range but also by difficulties of ammunition supply. They can therefore be used only under the conditions of position warfare.

5. Shells consist of time shrapnel shell, high explosive shell and special shell.

They are classified thus :—

Nature.	Fired by.	Action.	Employment.
		TIME SHRAPNEL SHELL.	
Time shrapnel	Light, medium and heavy guns.	The shell is burst in the air short of the target by the "time" arrangement of the fuze and a shower of bullets is projected from the mouth of the shell along the line of flight on to the target in the shape of a cone. The bullets form an ellipse covering an area which varies with the range and the type of equipment. The beaten area of 18-pr. shrapnel is 70 yards long at 3,000 yards, and 40 yards at 6,000 yards. That of the 60-pr. is naturally much longer. Time shrapnel becomes ineffective at ranges over 6,500 yards with the 18-pr. and 15,100 yards with the 60-pr.	Against troops in the open or under very light cover; for covering fire or barrages. Its forward effect makes it especially effective in enfilade.
		HIGH EXPLOSIVE AND SPECIAL SHELL.	
H.E. shell with instantaneous fuze.	All natures	The shell bursts immediately on impact, the body breaking into fragments which fly outwards mainly at right angles to the longer axis of the shell. The shell is intended to detonate (a far more violent action than explosion); detonation produces violent concussion. Unreliable at angles of descent less than 6°.	Against troops and guns in the open or under light cover; for covering fire or barrages, harassing fire and wire-cutting. For concussion effect against works constructed of concrete or masonry. Against tanks.
H.E. shell with non - delay fuze.	All natures	The action is similar to that of H.E. shell with instantaneous fuze, except that the splinter effect is reduced owing to a proportion of the fragments burying themselves, due to the burst taking place an appreciable time after impact. The crater effect is good and shell will burst at all angles of descent.	For destruction of buildings and strong cover other than concrete. For destruction of trenches by the crater effect produced and also against tanks.

Nature.	Fired by.	Action.	Employment.
H.E. shell with delay fuse	All natures	The shell has two actions, depending on the angle of impact and the surface of the ground. i. *Ricochet effect* (guns only).—If the shell ricochets into the air during the time of burning of the fuze, the shell will burst in the air; fragments fly laterally and downwards. Concussion effect is good. No crater. Burst may be as far as 70 yards from the point of impact, and 30 feet, or more, in the air. ii. "*Burst after penetration*" *effect.*—The shell buries itself and bursts under the ground. Subterranean crater is produced with concussion effect.	Against troops in trenches, prepared shell-holes and sunken roads; against the personnel of shielded guns and for covering fire or barrages with light artillery at ranges not exceeding 4,500 yards. Against strongly protected field works and permanent fortifications.
Incendiary shell	... ...	The shell is similar in action to time shrapnel, except that in place of bullets it is filled with discs or short cylinders which, on being ignited by the bursting charge of the shell, are projected forward as a shower of flaming "stars."	To set buildings, farms, hayricks, &c., on fire and to burn crops or undergrowth.
Star shell ...	Light and medium artillery.	i. *Shrapnel type.*—The construction is similar to that of an incendiary shell. When the shell bursts the burning stars are projected and fall to the ground. ii. *Parachute type.*—In this type the case contains a single star attached to a parachute. When the shell bursts the base is blown off, the star falls out and ignites and the parachute opening, sinks slowly to the ground.	For lighting up ground.
Smoke shell ...	Light artillery.	When the fuze strikes the ground it detonates the bursting charge, breaking up the shell, igniting and scattering the chemical contents. The ignition of the filling produces dense clouds of smoke.	To increase the screening effect of a creeping barrage, to mask hostile fire and deny observation to the enemy.

5. *Gas, smoke, mines, tanks and aeroplanes.*

1. **Gas.**—The design of defences will be affected only in regard to the sites selected for the trenches and in the accessories of trenches. It has

been found that trenches in woods and in the bottom of valleys are particularly affected by gas bombardments; the same applies to villages which have not been totally destroyed. The protection of dug-outs against gas is effected by means of curtains, the details of which are described in Sec. **66**.

2. **Smoke** can be produced in the form of a cloud from projectors, smoke cases, candles, rifle grenades, tanks, and aircraft, or by a concentrated bombardment by artillery or mortars using smoke shell. It is used to cover movement and to effect surprise. It can be used to screen the movement of troops, working parties, &c. (*see* Manual on the Use of Smoke, 1923).

3. **Mines.**—These influence the design of a trench system in the provision of special dug-outs for listening, arrangements for shaft heads, &c. Mine warfare is dealt with in Military Engineering, Vol. IV.

4. **Tanks.**—Tanks influence the design in the provision of emplacements of guns, machine guns and mortars to destroy them, and obstacles to hold them up or the infantry accompanying them under fire. The details of these measures are discussed under their own headings.

5. **Aeroplanes.**—The nature of attack by aeroplanes on troops occupying trenches will generally be machine-gun fire from low flying aeroplanes. They will use every endeavour to increase the effect of their attack by surprise, by diving rapidly from a height, or by swooping suddenly over the skyline where the field of view is limited. Protection against this form of attack can only be afforded by shelters, slit trenches as described in Sec. **53**, 2, or deep fire trenches with deep traverses.

In special cases bombs may be used; the protection against these would be similar to that against artillery fire. Otherwise aeroplane attack by bombing is usually confined to the attack on horse lines, camps, strategical centres, headquarters, railway and store depots, ammunition dumps, &c. In such cases protection must be afforded for personnel by deep or bomb-proof dug-outs, as described in Chapter XIV.

Aerial bombs vary in weight from 25 lbs. up to 660 lbs. or even heavier. They can be fitted with either an instantaneous or a delay action fuze. When fitted with an instantaneous fuze they are intended for use against personnel. Splinters from these bombs fly very horizontally and they have a powerful man-killing effect. A splinter from a 660-lb. bomb has penetrated a 14-inch brick wall. The crater formed is generally shallow.

When fitted with a delay action fuze the bomb may penetrate two or three stories of an ordinary dwelling house before bursting. The crater formed on grass land will vary from about 3 feet in diameter and 18 inches deep for a 25-lb. bomb, up to 30 to 40 feet in diameter and 20 to 25 feet deep for a 660-lb. bomb. One of the latter formed a crater 40 feet in diameter and 10 feet deep in a roadway paved with wooden blocks on 9 inches of good concrete.

Splinters from bombs fly very horizontally; consequently their effect can be limited by traverses of a reasonable height. Protection can be given in this way to troops in tents and huts, men in hutted hospitals and to horses in stables. The methods are described in Chapter XIII. A 9-inch brick wall or a revetted earth wall, 2 feet thick, will stop splinters from bombs hitherto used against troops in camps or horse lines.

CHAPTER II

TOOLS AND MATERIALS

6. *Tools.*

1. Every soldier must be able equally to march, to fight and to dig, and in order that he may dig efficiently careful training is necessary in the correct methods of using the tools available.

2. The tools generally used in field fortification are grouped under the following heads :—

Entrenching tools.
Cutting tools.

3. **Entrenching tools.**—These are the pickaxe, the shovel, the spade and the crowbar.

The most important are the pickaxe and shovel; to obtain a satisfactory result with them, men must be trained in their use as methodically and thoroughly as they are trained to use a rifle. To obtain the best value out of these tools, they must be kept sharp and clean.

The object of such training in the correct use of pick and shovel is to ensure the maximum output of work with the minimum of labour and fatigue to the digger. The pick and shovel drill best calculated to achieve this result is set out below. It has been evolved as the result of a comprehensive series of experiments.

While being trained, men must not be allowed to dig except under proper instruction, so that they may acquire the correct action from the start, and exercise the right muscles. They must be taught to use the pick and shovel with either hand leading, in order that they may be able to get out and throw the earth on either side of a trench, without changing position, and to work their tasks from front to rear to avoid risk of injuring their neighbours.

The **pickaxe** is intended for loosening soil; the pointed end is for use in hard, the chisel end in soft ground.

For safety in trench work, especially at night, the pick must be used working front to rear. Should the trench be too narrow to use the pick in this way, picking will be done from the left of the task.

The **shovel** is the tool for clearing away the soil loosened by the pick.

4. **Tools are issued** from stores as follows :—

i. *No time for preparation.*—Picks and shovels are stacked in separate heaps divided by a narrow passage, through which the men, with rifles slung, pass in single file taking up a pick with the left hand and a shovel in the right.

ii. *Time for preparation.*—Tools are laid out in sets, at one pace interval, shovel on the right, handles 18 ins. apart; irons of both to the front, point of shovel blade in line with the pick head. Those for the rear rank at three paces distance.

5. **Falling in with Tools.**—Men will fall in with rifles slung and tools at the trail, pick in the left hand, shovel in the right, irons of both to the front, point of pick downwards and face of shovel blade inwards.

6. "Ground Tools."—Take a short pace forward with the left foot, bend down and place the tools quietly on the ground, irons of both to the front, pick on the left, shovel on the right, face downwards, point of shovel blade in line with the pick head. The left hand to be three inches in front of left toe as it places the pick on the ground. Then return smartly to the position of attention.

7. "Take up Tools."—Take a short pace forward with the left foot, bend down, take up tools and return to the position of attention, tools at the trail.

8. **Turnings.**—Drop the head of the pick and raise the shovel blade, turn as ordered and bring the tools back to the trail. If in file at close order the handles should be allowed to splay outwards.

9. **Forming fours.**—Each man will act as above and the left files move as in squad drill, each man keeping his tools in the vertical position until the command "Right" or "Left" is given.

10. **Marching.**—Men should be exercised in marching with tools, turning on the march, forming fours, &c. in order that they may learn to handle the tools quietly.

When marching *at-ease* tools may be carried on the shoulder.

11. **Picking.—Right Hand Forward ; Right Foot Forward.**

Ready.—Turn half left and carry off right foot to right. Body evenly balanced on both feet. Pick horizontal in front of body. Both arms loose. Right hand about 4 in. from pick head. Left hand at small end of helve.

Raise.—Fix eyes on point to be struck. Raise pick over right shoulder, keeping right upper arm horizontal, centre of pick directly over right shoulder, left arm slightly bent across front of body. Right hand moves slightly towards left, weight of body on rear foot. (Plate 1.)

Strike.—Eyes on mark. Holding firmly with left hand strike downwards allowing helve to slip through right hand. At the moment of striking the ground both hands grip tightly, weight of body coming on to forward hand (Plate 1).

Break.—Force small end of helve upwards and move forward hand towards pickhead. (Plate 2.)

Rake.—Rake the loosened earth towards feet by pulling pick back with both hands. Weight of body on rear foot (Plate 2).

Raise.—Straighten the forward knee and trunk and continue. If necessary the "*Rake*" may be repeated before "*Raise*" by carrying the pick forward and raking.

The drill is continued by the repetition of the commands "*Raise,*" "*Strike,*" "*Break,*" "*Rake,*" as necessary. It is important to teach a regular rhythm and the rate should be from 28 to 30 strokes a minute for periods of from 15 to 30 seconds, followed by a short pause, during which, if it is desired to continue work with the shovel, the pick will be grounded and the shovel taken up.

Picking.—Left hand forward ; left foot forward.—The position of feet and hands and the action are reversed.

12. **Shovelling.—Right-handed. For Throwing to Left and Front.**

Ready.—Turn half right and advance left foot to left near loosened earth. Body balanced on both feet. Right hand on "T" with thumb round. Left hand grasping bend of shovel, palm up.

Swing and Fill.—Swing shovel back with weight of body on rear foot. Left arm straight and left hand near right knee. Right arm bent to incline shovel towards base of loosened earth. Swing body and shovel forward so that the pan slides along base, bending left knee, weight of body behind thrust.

Handle Low.—Depress "T" piece of helve to free shovel load from pile of earth (Plate 3).

Swing and Throw.—Swing shovel backwards just clear of ground until pan is over right toe. Weight of body on rear foot (Plate 4).

Cast the load away by a forward upward and slightly lateral swing, bringing weight on forward foot, left arm straight, shovel sliding slightly through forward hand, right arm directing shovel, the body straightened according to height of throw.

Aids.—For heavy soil or rough base. Place left knee against left fore arm and the inside of right thigh just above the knee against the back of right hand. Bend both knees with a crouching movement and bring the weight of body behind the thrust.

The drill is continued in quick time by the repetition of the commands "*Swing and Fill*," "*Handle Low*," "*Swing and Throw*." It is important to teach a regular rhythm and the rate should be from 18 to 20 throws a minute without aids, and 16 to 18 with aids. The period should be from 15 to 30 seconds, followed by a short pause, during which, if it is desired to continue work with the pick, the shovel will be grounded and the pick taken up.

Shovelling Left-handed. For Throwing to Right and Front.—The position of feet and hands and action are reversed.

In shovelling, men must be taught to slide the shovel under the edge of the loose earth, which must, if necessary, be scraped together before the shovel is filled. Unless a clear base is maintained on which to stand and along which to slide the shovel, work will be hampered, loose earth will be trodden in and much of the pick work will be wasted.

NOTES.—**Rest Pauses.**—During a long task, systematic pauses should be taken, *i.e.*, 8 minutes' work followed by 2 minutes' rest, with 5 minutes' work followed by 5 minutes' rest for the last 10 minutes of each hour.

Average work of 4 hours' task, 25 cub. ft. an hour.

Average shovel load, 10 lbs.

13. The **spade** is used for cutting sods and trimming slopes.

14. The **crowbar** has many uses; all ranks should be instructed in its use as a common lever for raising weights.

15. **Cutting tools.**—The service cutting tools are the felling-axe, hand-axe, bill hook, cross-cut saw, hand saw, and folding saw.

The felling-axe, cross-cut and folding saws are used for felling; the hand-axe, bill hook and hand saw for clearing brushwood, hedges, &c., and for trimming.

The **felling-axe** can be used with effect only by a man trained to use it. An axe in the hands of an unskilled man is a source of danger to himself and his neighbours.

The **cross-cut saw** is safer, easier and quicker in the hands of men unskilled in the use of the axe and is worked by two men who pull the saw in turn across the timber. No pushing is required. When used for felling, wedges are required to prevent the saw from jamming.

Where cutting tools are in use means to keep them sharp must be provided, *e.g.*, grindstones, saw sets, files and honing stones.

16. **Other tools in common use.**—Mauls, sledge hammers, augers and field levels. Men require practice with these to get the best value out of them. Mauls and sledge hammers must be used with a full arm swing. Augers must be screwed in vertically to the surface on which they are worked so that the hole may be true. The field level is described in Sec. 14, 2.

7. *Materials.*

1. A list of materials commonly used in the construction of field defences is given in Appendix VII, and their use is described in Chapter IX. The characteristics of some of the more common materials are given in the following paragraphs.

2. **Earth.**—Of all the materials used in the construction of field defences, earth is the most valuable and the one most generally available. In combination with timber, steel, concrete or masonry, it can be used in a great variety of ways for giving protection against projectiles. Earth slopes, when freshly cut, will stand nearly vertically for a short time, but quickly disintegrate and crumble after exposure to air, sun, rain and frost, and in time the earth loses its cohesion and will stand only at the slope of excavated earth. Alternate frost and thaw are particularly destructive to earth slopes.

Excavated earth stands naturally at a slope of about 1/1 to 2/3. To make earth stand at a steeper slope, it must be revetted (Sec. 60). The weight of earth varies from about 80 lbs. to 100 lbs. a cubic foot.

3. **Stones** in a parapet stop bullets, but cause damage from splinters and increase casualties if subject to artillery fire. In countries where there is no earth, stones are used to build defences of loose stone walls called sangars (*see* Appendix XI). Only the largest stones which can be handled should be used for such walls (*see* Sec. 62, 2).

4. **Sods** are pieces of turf cut 18 by 9 by 4½ inches; they are used for revetting and are used like bricks in brick work.

The best tools to cut sods are spades, the worst are shovels as their blades are curved and it is, therefore, difficult to cut the edge of the sods square. The use of handaxes for cutting sods is to be deprecated as it destroys their edge.

5. **Timber** in round logs, squared beams, scantlings or planks is used in nearly every detail connected with field engineering such as shelters, bomb-proofs, gun platforms, stockades, bridges, huts, &c.

Before felling timber, the trees should be carefully inspected to see that the most suitable are taken for the purpose, and the direction in which they are to fall should be carefully planned, so that time is not lost by trees falling into those which are standing, or on those which have already been felled.

To fell a tree in a required direction, cut into it as far as the centre on the side on which it is required to fall. Then strain it in that direction by means of a rope and finish off by a cut on the opposite side about 4 inches higher up.

6. **Brushwood** is used for roadmaking, hutting and revetting. Willow, birch, ash, Spanish chestnut and hazel are the most suitable kinds, and work best if cut when the leaf is off. It should be cut as low down as possible.

As a rough rule it may be taken that 1,000 square yards of brushwood, up to 2-inch diameter, make up three G.S. wagon loads.

If brushwood has to be carried any distance it should be tied into bundles, weighing about 50 lbs. If nothing else is available these may be bound with pliable rods called "withes," which should be well beaten and twisted before use (Plate **5**, Figs. 1 and 2). Brushwood can be made up into fascines or hurdles.

7. A **fascine** is a long bundle of brushwood tightly packed and bound, used for draining trenches, foundations of roads in marshy sites, and occasionally for making steps, &c. The usual dimensions are 18 feet long and 9 inches in diameter. It is made in a cradle of trestles placed at a uniform level as shown on Plate **5**, Figs. 3, 4, 5.

8. **Hurdles** are chiefly used for revetment and unless for a special object, are usually made 6 feet long and 3 feet high in the web (Plate **6**, Figs. 1 and 2).

To make a hurdle a line 6 feet long is marked on the ground and divided into nine equal parts, and a picket (about 3 feet 6 inches long and from 1 inch to 2 inches in diameter) driven in at each division, the two outside pickets being somewhat stouter and longer.

The web is then constructed by a process called randing which consists in working with single rods commencing from the centre. Each rod is taken alternate sides of the pickets, twisted round the end pickets and woven back towards the centre. A fresh rod must overlap by several pickets the one which it supplants.

Pairing rods (Plate **6**, Fig. 2) are used in the centre and at both ends of the web, which is usually sewn top and bottom in three places.

A rougher type of hurdle is shown in Plate **6**, Fig. 3. This is made much more quickly than the ordinary type and is equally efficient for most purposes.

Hurdles can also be made of expanded metal (X.M.P.) as shown in Plate **6**, Fig. 4. For convenience of carrying, the vertical stiffeners can be temporarily removed and the X.P.M. rolled up.

9. **Gabions** are hollow baskets or boxes, made of almost any material capable of being bent or woven into a cylindrical or square form, such as brushwood, expanded metal, stout canvas, wire netting, &c. Two patterns are shown on Plate **7** from which the general method of construction can be obtained.

The most convenient form is the square gabion made of X.P.M. (Plate 7, Fig. 5). It is made by bending a piece of X.P.M. round a stout rectangular framework 3 feet high with four 18-inch faces. The joint where the ends overlap is secured by a hurdle lacing of plain wire or other device (Fig. 6).

Gabions are used for revetments, hasty cover and repair work.

10. **Sandbags.**—The service pattern of sandbag measures 33 inches by 14 inches empty. It is made of jute bagging and issued in bales of 250, weighing 96 lbs.

Sandbags are used for revetments, loopholes, spoil bags for mining or dug-out work. For revetment, except in the case of the repair of damaged parapets or where silent work is essential, they are expensive, rot quickly, and require constant attention.

11. **Sacks.**—Grain sacks or bags which may be available on service can be substituted for sandbags.

They usually contain about 2 bushels ($2\frac{1}{2}$ cubic feet) of grain—if used for field defences they should not be more than half filled, otherwise they are too heavy to handle easily.

It is not necessary to close or tie up a sack if the mouth is carefully folded under it when it is being placed in position; the weight of the sack will prevent loss of earth.

12. **"A" frames** are wood frames specially made for revetting or repair of trenches (Plate 8, Fig. 1, and Plate 9). Their use is shown on Plates 48, Fig. 3 and 51, Fig. 2.

Trenchboards are wooden gratings of the dimensions shown on Plate 8, Fig. 2. They are used to give a firm footing in trenches in combination with "A" frames (Plates 51, Figs. 2 and 3 and 48, Fig. 3) or on overland tracks.

8. *Method of distribution of tools, stores and materials.*

1. All tools and materials in excess of those included in the War Equipment Tables of units and formations, A.F. G 1098 series, required for field engineering, are supplied through the engineers. In each formation from the base to the front, engineer parks, stores or dumps as they are more generally called, are organized, and the channel of supply is from the base engineer store and ordnance depots through the army and corps parks to the divisional engineer dumps.

2. In position warfare the divisional organization for the distribution of engineer stores is as follows :—

The main divisional dump is situated, if possible, on a light railway by which it is fed by the corps dump, and is in such a position as to be reasonably immune from interference by the enemy's shelling.

An advanced divisional dump is formed in advance of this, usually on a road where transport can deliver by day and can be loaded and sent forward by night; it should also be on the light railway.

In front of this the brigade dumps are situated as far forward as horse transport can go at night, or at the light railway railhead and adjacent to the tramway, existing or projected.

During offensive operations it is frequently necessary to form special (trench) dumps, which are stocked with articles required for the work of consolidating the objective, and these stores are not drawn upon for ordinary and current work. They are under the control of the infantry commander.

3. In mobile warfare this organization must be modified according to circumstances.

4. A list of principal tools, materials and stores suitable for use in field engineering is given in Appendix VII.

CHAPTER III

THE ORGANIZATION OF WORKING PARTIES AND THEIR TASKS

9. *Responsibility for the execution of work.*

1. All arms are responsible for the construction of their own defence works with such assistance as may be available from the engineers (*see* Sec. **17**, 2, F.S.R., Vol. II, 1924). Such work will include the provision of cover from fire and the construction of obstacles. Field works should be regarded as a military duty and should be executed as a military operation.

Commanders of formations and units will be responsible for siting, organizing and constructing field defences. Officers of all arms must study the most suitable types of defences and the details of siting, depending on armament, ground, concealment, &c.

The engineers will normally be employed only on works requiring technical skill, special tools, or specially elaborate organization in connection with the main zone or rear position defences in position warfare. There are not enough engineer units available with formations to enable the engineers to undertake any but this technical work.

2. Field works may, therefore, be divided into two classes :—

i. Work for which units or formations other than the engineers are responsible. This will be carried out under the orders of unit commanders with materials supplied by the engineers, but without engineer assistance or supervision other than technical advice or minor assistance in technical details, such as fixing of timbers in complicated shelters, &c. The provision of this technical advice or minor assistance is the duty of engineer liaison officers with the formations.

ii. Work for which the engineers are responsible. This will be carried out solely by engineer units, or by engineer units with the assistance of working parties from infantry or other units, or civil labour.

In the case of work under class (ii) and frequently also under class (i), there will be two principal officers involved in the work.

(*a*) The engineer or other officer in charge of the work.
(*b*) The officer in command of the working party.

3. The responsibilities of each are as follows :—

i. **The officer in charge of the work** is responsible for—

(*a*) Making the preliminary reconnaissance.
(*b*) Tracing out the work.
(*c*) Demanding the working party.
(*d*) Supplying materials and extra tools, if necessary.
(*e*) Supplying guides to ensure that the working party actually arrives on the site of the work.
(*f*) Seeing that the work is completed as designed.

He must also see that arrangements are made for provision of any covering party that is required, in addition to the working party.

ii. The officer in command of the working party is responsible for the disposal of the men on the work, for seeing that all orders regarding lights, smoking and talking, &c., are strictly obeyed, for the diligence of his men, and, if desired by the officer in charge of the work, for measuring up the tasks to see that they are correctly finished and for withdrawing the party when he is satisfied that the work is completed in accordance with the designs previously explained to him by the officer in charge of the work.

It is also his responsibility to decide whether in the event of suffering serious casualties the men should be temporarily withdrawn or an attempt made to carry out his task at all costs. If heavy casualties are anticipated, the authority which orders the work must give definite directions as to its relative urgency.

10. *Alternative methods of organizing working parties.*

Whether engineers or other arms are responsible for the work the principles of organization laid down in this and succeeding sections will be acted upon.

For straightforward work, where daylight reconnaissance out of enemy observation is possible and when there is sufficient time to make the necessary reconnaissance and to send the "demands" back to brigade or battalion headquarters, the procedure in Sec. 11 should be followed.

It must be recognized, however, that enemy observation and urgency (which may limit time for reconnaissance) make modifications necessary.

The time taken to carry out all the steps and duties detailed in the notes, including the sending back of the "demands" and subsequent detailing of, and the approach march of, the working party, may be eight hours or more.

If the time available is less than eight hours, a working party must be detailed and the rendezvous and time fixed, before the reconnaissance is made.

Details of this procedure for hasty work are given in Sec. 12.

No work should be carried out at night which can be done by day. But it is often essential either on account of the presence of the enemy, or for purposes of concealment, or to gain time, for field works of every kind to be done at night.

In this case the organization of work and the previous reconnaissance are of peculiar importance owing to the very great difficulty of guiding and putting parties on to work in the dark.

11. *Procedure when reconnaissance is possible before sending in demands.*

1. Immediately on receipt of orders to put any work in hand, the officer who is appointed to take charge of the work, accompanied by a staff officer or a representative of the unit concerned, will visit the site, by daylight if possible, to make a reconnaissance of the work. This reconnaissance enables him to decide on the approximate numbers of the working party, what types of tools and materials are required and whether there are any particular difficulties in carrying out his orders, *e.g.*, hard ground, roots, &c., which call for special measures to meet them.

Whenever the conditions of the operations permit, in order to save time, he should take with him a tracing party of suitable strength to mark out the work, and the guides which will be required to direct the working party from the rendezvous to the work. If possible, the officer who will be in command of the working party and some of his N.C.Os. should take part in this reconnaissance.

Before starting, the party should be informed where the work is, what it is, and its purpose. Note should be taken of the following points :—

i. The route to the work which involves the least fatigue and delay and the time required to march to it; plenty of time must be allowed, remembering that a large party moves very slowly, especially across country or in trenches in single file. If the enemy's harassing fire is heavy it may be necessary to tape out routes across country which will involve special measures being taken to cross trenches.

ii. Landmarks which assist in locating the site of the work and the route to be followed; if none exist, artificial marks should be erected.

iii. The guides should be shown the rendezvous at which their parties will be ordered to report, if it has been decided upon.

The work should next be marked out; the officer commanding the working party, if present, will decide in consultation with the officer in charge of the work, how best to distribute his men; this should be done by platoons and companies, so that each commander shall interest himself in the work of his men, as he is responsible that it is completed.

The limits of each platoon and company should be clearly marked, and each guide should be shown the point to which he is to bring his party and the extent of its task. The formations in which the party are marched to the work depend upon the amount of interference the enemy will bring to bear, but there should be no bunching on the march up, and the arrival of the parties must be so timed that one party does not have to wait while another is being put on to the work. In normal times, the rate of arrival should be 50 men (actual workers) at 15 minutes' interval, and when harassing fire is heavy 25 men at 15 minutes' interval.

With carrying parties the loads should be so distributed that it is possible to carry on if a portion of the party fails to arrive.

If it has not been possible for the guides to go over the ground, they should be given their instructions in writing, but in any case they must be at the rendezvous punctually.

2. The officer in charge of the work must now make a rough estimate of the amount of each sort of work, such as clearing, entanglements, digging, carrying, &c., and by the help of the tables in this book (Appendices III and VI) or his own experience of the abilities of the men who will form the working party, he will be able to make an estimate of the number of men and tools and of the materials he will require. When entrenching, the normal interval between men is 6 feet, 5 feet is the minimum interval.

It must not be supposed that, under active service conditions, this estimate will be accurate, but it will be near enough to enable him to form a fair idea of the size of the working party and of the time required to complete the work, or, if the time is definitely laid down, how many men will be required to complete the work in a given time.

If too many men are detailed, the working party is crowded together and the risk of noise and consequent heavy casualties is increased; also, while the work is not speeded up, a greater number of men are deprived of their night's rest, and the efficiency of the unit as a whole is impaired.

If too few men are detailed they become disheartened, and in consequence, turn out less work, the completion of the work is unnecessarily delayed and the risk of interference by the enemy is increased.

The number of men which can be fully employed on a given work will depend largely on the thoroughness of organization; generally, overcrowding on work is due more to lack of organization than to excessive numbers.

On active service the actual strengths of formations vary so quickly from day to day that it is generally impossible for the officer in charge of the work to demand his working party in the form of so many companies, platoons, &c., however desirable this may be. His original demand for a working party submitted to the proper authority, must be based on the estimated number of tasks or men required to finish the work in a given time. It is the duty of the officer commanding the unit providing the working party to detail the numbers of actual workers required by units, *e.g.*, battalions, companies or platoons. This ensures that the men work under their own officers and that a proper proportion of N.C.Os., stretcher bearers, &c., is also detailed. It may not be possible to adjust these exactly, but the importance of detailing complete formations as against detachments of certain numbers is paramount.

3. A detail of the tools required involves a knowledge of what tools are available and where they are carried. Details may be obtained from the Field Service Pocket Book, A.F. G 1098 of the unit providing the working party, and Appendix V; the carriage of these tools is given in the Field Service Manuals. For the simplest forms of work the proportion of tools in Appendix III will give a guide as to what is required in ordinary circumstances.

In position warfare when tool dumps are formed, all tools will be drawn from and returned to the dumps.

4. Having arrived at the numbers of men, the tools and the materials required, the officer in charge of the work has these additional duties:—

i. To fix exact location of the rendezvous where the working party is to assemble, where the stores and extra tools are to be dumped or drawn, and where his guides will meet the working party to conduct them to their work, and to notify this to all concerned. The rendezvous should be on the way up to the work, but not necessarily near it. It must be distinctly marked (a map reference is not enough) especially if the party arrives at the rendezvous after dark, and should be near some sort of cover.

It must not be conspicuous from the enemy's point of view, *e.g.*, a cross road, a lone tree, or an isolated building. In a trench system, it should not be a trench junction except when the working party is detailed from the troops holding the trenches.

ii. To fix the hour of arrival at the rendezvous. This must be carefully worked out so that the men are marched from thence to their work without delay. If men are kept hanging about in the dark they fall asleep and are difficult to rouse.

The enemy's observation and the state of the light must also be considered. Work at night should commence just after dusk or before moon-rise.

iii. To arrange for the necessary materials, tools, &c., and for transport of the same; and to ensure delivery of these at the rendezvous before the arrival of the working party.

iv. To see that arrangements are being made for the provision of any covering party that may be required, so that there is no risk of the working party being reduced by having to find the covering party out of the numbers detailed for work.

He is now in a position to submit his demand for the necessary working party for work which will occupy a certain number of hours, stating the hour at which they must be at the rendezvous with a certain proportion of tools from their own equipment, and haversack rations, if necessary, and where they will meet guides provided by him and draw additional tools and material as may be required for the work in hand, which they will carry or escort in the transport he provides to the site of the work, which the tracing party has already marked out on the ground, and on which the working party will be extended, while they are protected by the covering party, which will be in position before work is commenced.

The demand for the working party should be made out in quadruplicate. A typical form is shown in Appendix I.

On receipt of this demand the headquarters of the formation will issue orders to the unit supplying the working party, which will ensure that the party meets the guides and brings the necessary tools, &c. A typical form for these orders is shown in Appendix II.

When the work is continuous over long periods, much clerical labour can be saved by the headquarters of the formation responsible for the work issuing, without demand, orders giving full particulars of all daily working parties and the unit responsible for providing each.

Fictitious names, which should obviously be of an engineer nature, are allotted to the guides, and these names should always be permanent, *i.e.*, the guide for No. 1 Party will always be Sapper Shovel, whatever his real name may be, or however often he may be changed.

5. If the **officer in command of the working party** has not been present at the tracing out of the work he will, in consultation with the officer in charge of the work, decide upon the best method for distributing his men on the work. The nature of the work and the task before them should be thoroughly explained to all ranks before they arrive on the work.

6. **Extending a working party from the left.** An officer or N.C.O. will stand at the left of the line on to which the squad is to be extended, prepared to pace or measure out each man's task. The squad will be formed into single rank at a convenient distance from the line and marched up in single file, tools at the trail and rifles slung, at right angles to the line, until the leading man is within two paces of the officer (or N.C.O.) charged with pacing out the task. The officer will then indicate the left of the task and the leading man will step forward and drive the point of his pick into the ground at that spot, helve to the rear. The officer will then pace out the task and the man will lay his shovel to the right along the line of his task, blade to the left, and face downwards. The second and remaining men will wheel to the right until opposite the left of their tasks when they will wheel to the left and carry on as detailed for the leading man.

After each man's task is paced out he will wait till the remainder of the squad in rear of him are clear and will then unsling his rifle, turn about, take six paces, ground arms, return to his former position and lie down until the order to commence work is given.

In extending from the *right* the procedure is similar to the above, the men wheeling to the left and right instead of to the right and left.

Alternative method.—The leading man goes right through to the far end of the work and the remainder space themselves out behind him along the line of the work. The commander of the party then checks and corrects their intervals, starting from the leading man and working backwards. In this method, although it takes slightly longer than the first method, the men are always well extended. The tendency to close up when the front man halts for fear of losing touch in the dark must be checked.

Working parties of second or subsequent reliefs on trench work should not be allowed to move along the partially dug trench, unless the tactical situation demands that they should do so.

The rapid and silent extension of parties in the dark is always difficult, but it will be rendered very much easier if the parties can be practised on the previous day in extending over a similar trace. The success of a night's work depends very largely on getting a good start.

7. When working in close contact with the enemy, the commander of the party may decide to work with arms slung; this greatly hinders the work and should not be done unless there is danger of attack. In the forward area it is generally sufficient if each man lays out his arms and equipment close at hand for use in an emergency. When the work is below fire step level and there is danger of an attack, arms should be laid on the parapet and all the earth should be thrown on to the parados.

In rear areas arms and equipment may be left under guard in a convenient spot.

Anti-gas respirators must always be in the alert position within the *alert zone*, or in areas likely to be bombarded by gas shell.

8. Work can be carried out either by :—

Task work, *i.e.*, a definite amount of work is given to each individual or preferably each formation, *i.e.*, section, platoon or company ; or

Time work, *i.e.*, the working party is required to work for a certain number of hours.

Task work should be given whenever possible.

In most work, especially that of a straightforward nature like digging or wiring, better and quicker work is obtained by **task work.** The allotment should be by small units, *e.g.*, sections, platoons, &c., and each party must be allowed to withdraw on the completion of its task ; this is the whole essence of task work.

Great care and considerable experience are required in setting tasks and, when once fixed, they must not be altered even if they have been wrongly estimated. Some figures showing the amount of work to be expected are given in Appendix III, but the figures may require modification according to the distance the men have to march to and from their work.

When working with reliefs on task work, care must be taken that all parties of one relief have finished their tasks before the arrival of the next, so that the latter are not kept waiting. An interval of 30 minutes should be allowed between the estimated time of the first relief finishing and the arrival of the second relief.

Supervision over task work must be strict, and the tasks which are usually on the easy side must be rigidly enforced. In deliberate trench work the dimensions of the trench should be checked by a templet, *i.e.*, a skeleton pattern of the section of the task, to ensure that the trench has been dug to full dimensions.

A templet or a 6-foot rod, should be carried by each platoon commander, by which he can explain the task.

9. It has been proved that the best is got out of a working party in 4 hours—after that period, the men tire rapidly, and the amount of work they do will seldom justify their being kept out.

Work in the face of the enemy is carried out during hours of darkness and in single reliefs, but it may happen that work must be done in continuous reliefs, that is, a fresh working party is provided every 4 hours.

Continuous reliefs are difficult to manage in the case of large numbers.

Relieving parties should not pass each other on their way to or from their work. There must be an up-and-down route in a trench system: communication trenches must be definitely allotted as up-and-down routes by the general staff.

If task work is being used, it is essential that all tasks shall be thoroughly cleaned up before the men leave work, or there will be abundant occasion for grumbling.

Each relief should arrive complete with all tools required for work and should return them to the dump from which they were drawn. It is not possible to hand over tools from one relief to the next in the dark.

If the work is being carried out in single reliefs at night, a clearing-up party should be detailed for work in daylight in order to square up the trenches and correct faults, and leave the trench fit for straightforward task work for the next relief.

This party must not be so numerous as to attract the notice of the enemy.

12. *Procedure when demands have to be sent in without previous reconnaissance.*

The following procedure should be followed when there is not sufficient time to send back "demands" after making a reconnaissance of the work:—

i. Orders are issued by higher authority to engineers and infantry to carry out the work.

ii. The officer in charge of the work at once sends in the following information, based on previous knowledge of the ground and large scale maps:—

(*a*) An estimate of the numbers of the working party.

(*b*) Details of tools to be carried, or tools or stores to be picked up at the rendezvous.

(c) Rendezvous for the working party.
(d) Time for the working party to be at the rendezvous.
(e) Duration of work.
(f) Probable time of arrival back in billets.

He will also:—

(g) Detail guides to lead the working party from the rendezvous to the site of the work.
(h) Request that the officer in command of the working party with officers or N.C.Os. representing companies or platoons, be at the rendezvous 1 hour before the remainder of the working party arrives there. This party will be guided immediately on arrival at rendezvous to the site of the work where the officer in command of the working party will meet the officer in charge of the work.

iii. The officer in charge of the work, with tracing party and guides for working party, proceeds from rendezvous to site of work, where a reconnaissance is made and work marked out. If under enemy observation, this marking out may not take place until dusk.

iv. The officer in command of the working party with party enumerated in ii (h) above, on arrival at rendezvous 1 hour before the remainder of the working party, is guided by the guide detailed by the officer in charge of the work to site of work, where he meets the officer in charge of the work, who explains the task in hand, and hands over necessary templets.

v. The officer in command of the working party decides how to distribute his companies and platoons.

vi. Main body of working party, on arrival at rendezvous at appointed time, is taken by guides to site of work, where under the instructions of the officer in command of the working party, the men are marched at once straight to their tasks.

13. *Tracing and setting out work.*

1. In order to avoid delay, any work that is to be executed should be marked out beforehand by tracing tapes (each tape is 50 yards long), or Hambro' lines, pickets, spitlocking, &c. The following instructions refer to tracing trenches, but they apply in principle to setting out wire entanglements, roads, tracks, tramways, &c.

Tracing has to be done frequently by night, in which case preliminary reconnaissance is important; the direction should be checked at frequent intervals by compass or by measuring the distance at right angles to a known line, such as the front line trench in the case of a tape laid for wire in front of forward positions. The steel helmet and box respirator must be taken off before the compass is used; both these articles of equipment affect it.

All officers, warrant officers and N.C.Os. should be practised in tracing by day and by night.

2. In the case of deliberate defences, if the line is marked by flags (Sec. 44), the trench should not be laid out in a series of straight lines from flag to flag; but each fire-bay should be carefully sited and marked with pegs by the tracing officer; the traverses should be fitted in by a N.C.O. following behind.

Similarly, if the line is marked by a ploughed furrow, this must not be slavishly followed in tracing the fire-bays.

3. Types of trace are illustrated on Plates **44, 45, 46,** and **47**; they may be applied to the ground by:—

i. Varying the angle of the traverse. This angle, must, however, never exceed 135°, or be less than 90°.

ii. Varying the length of the fire-bays, or of the legs of the traverses.

iii. Changing direction in a fire-bay.

4. With the bastion trace (Plate **44**, Fig. 2), until experience in laying out has been acquired, a tape templet should be used (Plate **10**, Fig. 1). This consists of a quadrilateral of tape of the dimensions of a normal traverse with two diagonals of tape to act as braces. It must be regarded as a guide, and not as a standard pattern for a traverse. After some practice, it is quicker to dispense with the templet, the sides of the traverses may be paced and the angles judged by eye.

5. The front limit or "cutting line" of a fire trench is the line which should be traced, but it is a great advantage, if sufficient tape is available, to trace both sides.

6. **Organization of tracing parties.**—The party should be divided into groups as follows:—

i. An officer and 1 O.R. with extra men as carriers. The officer traces out the fire-bays, driving pegs in at the ends of them; he must select the position of each fire-bay with regard to the shape of the ground.

ii. An experienced N.C.O. and 2 men with extra carriers if necessary. If a templet is used, it is laid out with its two front corners near the inside pegs of two adjacent fire-bays, and the back pegs of the traverse are driven in near the back corners of the templet, under the direction of the N.C.O.

iii. A number of men, varying with the nature of the ground, to clear crops, bushes, &c., from the line of the tape.

iv. One man running out the tape and fixing it to the pegs, with carriers for extra tape.

The duties of the various parties are tabulated below:—

Party.	Composition.	Tools and stores.	Duties.
No. 1	1 officer, 2 or 3 men.	1 mallet, bundles of pegs.	Peg out fire-bays.
No. 2	1 N.C.O., 2 to 4 men.	(Tape templet) 1 mallet, bundles of pegs.	Peg out traverses.
No. 3	As required by nature of ground.	Reaping hooks, &c....	Clear line for tape.
No. 4	2 or 3 men.	Tape	Carrying tape and fixing to pegs.

Total: 1 officer, 1 N.C.O. and 6 or more men, depending on the amount of material to be carried, and the amount of clearing to be done.

7. Wire entanglement coil staples or wire "hairpins," are good substitutes for pegs; the tape is laid very loosely at first, and then pulled back taut round the traverses (Plate **10**, Fig. 2).

CHAPTER IV

FIELD LEVEL AND FIELD GEOMETRY

14. *Measurement of slopes and laying-off angles.*

1. **Slopes** are usually described in field works by fractions, in which the numerator expresses the height, and the denominator the base of the slope. Thus a slope, described as 4/1 (*i.e.*, four in one), is one in which the vertical height is four times the base (Plate **11**, Fig. 1); whilst that expressed by 1/6 (*i.e.*, one in six) is, on the contrary, one in which the base is six times the vertical height (Plate **11**, Fig. 2).

To convert angles of slope, given in degrees, into fractions as used in field works, a rough rule is to divide 60 by the number of degrees in the angle. Thus 6° = 1 in 10 roughly. This rule should not be used for angles greater than 30°.

2. **Field level.**—In the laying out of field defences certain simple geometrical operations may be necessary. The only special instrument employed for the purpose is the field level, which is used for setting off angles on the ground, and for gauging slopes.

The level is shown on Plate **12**.

The limb C, which contains the spirit level, must be opened out first, and afterwards the limb B; these are then joined by a catch at X.

The level is used in the following ways:—

i. As an ordinary spirit level, as used by a carpenter or a pavior; for this purpose it need not be opened at all (Plate **12**, Fig. 4).

ii. As a square for setting off right angles. The limbs B and C form the right angle (Plate **12**, Fig. 1).

iii. As a protractor, for laying out an angle from a given point on a given line. The limb A is made to coincide with the line, the point of the arrow head being at the given point. The required angle can then be laid out by stretching a tape from the arrow head over the angle as numbered on limb B or limb C (Plate **12**, Fig. 1).

iv. For setting off any slopes from the horizontal to the vertical as a mason's level. For this purpose the plumb-bob, kept in a recess of limb C, is required. The plumb-bob must be suspended from the brass socket in limb C (near the end remote from the spirit level), and allowed to swing freely, and the level moves until the string coincides with the required angle ½, &c.; the edge of the limb A will then be at the required slope (Plate **12**, Figs. 2 and 3).

v. One side is graduated in feet and inches and can be used as a four-foot rule (Plate **12**, Fig. 4).

3. The **improvised level** shown in Plate **13** may be found useful. By means of it a series of points, A, B, C, D, E, F, G, H, I, on the same level, can be fixed and marked by pegs. Suppose AI is 40 yards and the difference of level of the drain or trench between A and I is found to be 1 foot, then the fall is 1½ inches each length of 5 yards; the bottom of the drain or trench can be graded by measurement from A, B, C, &c.

15. *Field geometry.*

1. In some of the more technical operations of field engineering, such as the construction of bridges and in road and camp work, a knowledge of the following applications of simple geometry in the field will often be of use. No special instruments are required for this purpose.

2. To lay out a right angle. Let X be a point in a given straight line AB (Plate **11**, Fig. 3), from which it is required to set off a right angle.

From X measure off a distance of 4 units XC along AB. Take a piece of line or tape 8 units long, apply one end to point X, and the other to point C; find a point in the tape 3 units from X, and, seizing it at this point, draw the bight out to D, till the line is taut, then CXD is a right angle. For example, if 1 foot is the unit—XC = 4 feet, XD = 3 feet and CD = 5 feet. The longer the sides of the triangle, the more accurate will be the right angle, and it will be found that when laying out long lines, such as a parade ground, or football ground, the sides of the triangle should not be less than 16 feet, 12 feet, and 20 feet.

3. To trace a perpendicular to a given line from a point outside. Let X be the point outside the line AB (Pl. **11**, Fig. 4), from which it is required to draw a perpendicular to that line. Take a tape or cord longer than the perpendicular will be; fix one end at X, and stretch it taut, so that the other end shall cut AB in C. Drive in a peg at C, find D, the middle point of CX. With D as centre, swing DX or DC round to the position DE, cutting AB in E. Join XE, then XE is at right angles to AB.

4. To lay off an angle of 60° or 120°. Let X be the point in the line AB (Pl. **11**, Fig. 5) from which it is required to lay off an angle of 60°. Take any point C in AB towards that end of the line from which the angle of 60° is to be drawn. Take a tape or cord twice the length of XC, and fasten the ends to X and C. Seize it at the middle and draw the bight out taut to E. Then the angle EXC is 60° and AXE is 120°.

5. To bisect a given angle. Let ABC be the angle which it is required to bisect (Pl. **11**, Fig. 6). In AB take any point D. Fasten the end of the tape at D, and take it round B and back again to D. With the length thus found mark E in BC and make the loose end fast at E. Take the centre of the tape from B and stretch it tight in the position DFE. BF will bisect the angle ABC.

6. To lay out an angle equal to a given angle. Let X be the point in the straight line AB (Pl. **11**, Fig. 7), from which it is desired to lay off an angle equal to the angle DEC. In the bounding lines of the angle DEC take any two points DC, and from X measure XG equal to EC. Take a tape equal to CDE. Put the ends at C and E, and make the tape cover CDE. Holding the tape by the point above D, transfer the ends which were at E and C to X and G respectively, and pull the tape taut. Then the point which had been at D will be at some point F, and the angle FXG will equal the angle DEC.

7. To find the distance between any two points A and B when it cannot be measured directly. From B (Pl. **11**, Fig. 8) lay off the line BD as nearly at right angles to AB as possible, D being at any convenient distance. In BD select a point C so that BC is some multiple of CD. From D lay off the angle BDF equal to the angle ABD, and on the opposite side of the line BD. Make DE of such a length that the point E is in line with A and C.

$$\text{Then AB : BC :: DE : CD,}$$

$$\text{or AB} = \frac{\text{BC} \times \text{DE}}{\text{CD}}.$$

CHAPTER V

A DEFENSIVE SYSTEM

(*See* Chapter IX, F.S.R., Vol. II, 1924, and Chapter III. Infantry Training, Vol. II, 1926.)

16. *General principles.*

1. The object of the defence is to wear out the enemy and to gain time. The defence can be assisted by making the best use of the ground, reinforced by the artificial aid of field works.

Economy is essential both in the number of men required to hold a given area and in the time, material, and labour involved in the preparation of the defences.

2. The principles of defensive action are laid down in Chapter IX, F.S.R., Vol. II, 1924, and may be summarized as follows :—

i. Defensive positions, however strong, are of no value unless their defenders have the will to defend them to the last.

ii. The position selected must be strategically important, otherwise the assailant will be under no obligation to attack it, and the defender must inevitably conform to his movements.

iii. The object of the defending troops is to inflict the maximum loss on the enemy at the least expense to themselves, and so to wear down his fighting power, while maintaining their own, that they will be able at a suitable time to resume the offensive and complete his defeat ; therefore everything possible must be done to economize man power in the defence, in order that the maximum power may be available for eventual offensive action.

iv. Defence in depth is essential to resist an attack supported by modern weapons. In arranging for the disposition of a given force, a balance must be struck between the frontage taken up and the depth to which the force is distributed.

17. *Choice of a defensive position.*

The tactics and armament of the enemy, considered in conjunction with the nature of the ground, will indicate which of the following considerations should carry most weight in the choice of a defensive position :—

i. The defensive battle should be fought in advance of localities, the retention of which is vital to the defender.

ii. The framework of the defence will be the artillery and machine guns. The positions, therefore, should permit of good ground observation and concealment for the guns, whilst denying these advantages to the attacker. The foremost defences should be far enough in advance of the localities selected for artillery observation to ensure that the eyes of the defence will not be blinded by the capture of these localities as the result of a minor attack by the enemy. Full consideration must also be given to anti-tank defence. If the enemy is well provided with tanks, infantry defences will be sited, wherever possible, in localities protected from tank attack.

iii. The extent of the position should not be too large for the number of troops available for its defence.
iv. The flanks should be naturally strong.
v. Surprise is just as important in the defence as in the attack. The position should, therefore, afford facilities for concealing the defender's dispositions from air and ground observation, and permit of covered movement within and in rear of the position.
vi. There should be ample room and good communications within and in rear of the position for manœuvring reserves, and the ground should afford facilities for counter-attack.
vii. There should be no localities outside the area to be defended, the occupation of which by the enemy would exert an unfavourable effect on the defence of the position.

18. *Reconnaissance.*

*1. The reconnaissance and siting of a defensive system is carried out by representatives of the general staff, the artillery, the engineers and the machine guns working together and co-ordinated by the general staff.

It is necessary to study a map of the area in question before going on to the ground; a layered map 1/100,000, or ½-inch to 1 mile, is suitable. A plan or several alternative proposals should be prepared after consideration of the important tactical features, observation, lines of approach, and ground which must be denied to the enemy. The approximate line in front of which it is intended to stop the enemy should be marked on the map.

It will save much time if flags can be erected beforehand in prominent places along this line, in order to assist the reconnoitring officers in picking up the general direction of the position from time to time.

Consideration should be given at this stage to the division of the position into sectors in accordance with the proposed allotment of formations (corps, divisions, brigades, &c.) for its defence.

2. After this preliminary reconnaissance, a conference should be held of the above representatives to decide on compromises necessary. This will be followed by a final visit to the ground, at which a more detailed plan will be made of the above-mentioned line, the artillery positions and observation posts, the machine-gun positions and their zones of fire, the important tactical localities to be defended, the main lines of obstacles, and the communications necessary within the position. These positions should be marked with small flags or wooden pickets.

3. Where time is short the final decisions may have to be made at the first visit, particular attention being paid to the junctions of formations.

19. *Organization of a defensive position in mobile warfare.*

1. All defensive systems should be planned from the outset in such a way that they can easily be adapted to the requirements of a prolonged defence.

2. The first essential is to decide on the general line in front of which it is intended to stop the enemy, and all defensive preparations will be based on the defence of this line. The troops allotted to its immediate defence will be distributed according to the accidents of the ground, in positions from

which they can best develop the fire power of their weapons. This will usually result in the holding of a chain of localities mutually supporting each other by frontal, flanking or enfilade fire, and covered by the fire of the longer ranging weapons echelonned behind them. Behind these localities, reserves will be distributed in depth for the purposes of counter-attack. In the distribution of these reserves, special attention must be paid to the security of the flanks.

3. Machine guns form the framework on which the infantry defence of the position is built. They must be sited in sections or pairs so as to bring direct fire on the ground up to at least 500 yards from the guns. Their main zone of fire should be in enfilade so as to sweep the flanks and front of tactical localities, and to cover the approaches open to the enemy. Direct fire is their primary role.

Careful concealment for machine guns is essential. The use of enfilade fire facilitates this, as positions can often be found which are defiladed from the front.

Alternative positions must be prepared to which guns can be moved if required, and short lengths of well-concealed trenches provided to give cover to the detachments.

4. Artillery should be distributed in depth and should make the utmost use of its mobility to deceive the enemy, protecting itself by the use of alternative positions.

By means of the light automatic guns with which batteries are provided, artillery is in a position to repel by its own fire the attacks of an enemy who has broken through the defences of a system, and may thus furnish rallying points behind which the infantry can re-form for counter-attack. Whenever time is available the positions of these guns should be protected by wire entanglements and should be sited mainly with a view to flank defence.

5. After the artillery and machine-gun positions have been decided upon and adequate observation ensured for the artillery, the **infantry defences** will be sited, full consideration being given to the importance of having natural anti-tank obstacles (woods, rivers, marshes, &c.) for their protection. If a good view of the ground over which the enemy must advance can be obtained by the artillery and machine guns, there is no necessity for the foremost infantry position to have a long field of fire. The defence is strengthened by these positions being concealed from ground observation, and although a long field of fire is advantageous in order to obtain the full power of rifle fire, a minimum field of fire of 100 to 150 yards may suffice.

The infantry defence will usually consist of a series of defended localities (Plate **14**) sited in depth and of a sufficiently large area for a platoon or larger unit to be allotted to the defence of each.

The internal organization of these localities should be in the form of a series of defended posts for sections or corresponding unit.

These posts should consist of short lengths of fire trench, allowing 5 to 6 feet for each man, from which all-round fire is possible (Plates **15** and **16**).

They should mutually support one another and be connected up laterally and from front to rear by communication trenches to the neighbouring posts as time permits.

Similarly, in the event of a prolonged defence the defended localities so formed would be connected by trenches to facilitate communication, and to prevent the enemy ascertaining by means of air photographs the position of the actual fire positions.

6. The units in reserve will also occupy a series of defended posts, but probably more concentrated than in the case of forward units, and sited so as to allow movement from them being carried out under cover.

7. It must be remembered that posts which adequately protect the intervening ground with their fire when observation is good are often unable to do so at night or in mist or fog, and that it may be necessary to establish connecting posts to prevent the enemy penetrating the position.

8. Temporary occupation of a covering position in advance of the main position is advisable when time and circumstances admit.

Dummy trenches, unexpected obstacles and well-concealed fire positions from which withdrawal can be made under cover, tend to mislead the enemy as to the real nature of the defensive arrangements, and may cause him to deploy prematurely or in a false direction.

9. The defences at the junction of formations require very careful siting and co-ordination.

20. *Organization of a defensive position in position warfare.*

1. Whether the time for preparation be long or short the general arrangements adopted will be similar to those laid down for the defence in mobile warfare.

In view, however, of the protracted nature of position warfare, it must be anticipated that the enemy will, sooner or later, concentrate powerful forces of artillery, mortars, and other mechanical means of destruction. Distribution of the defence in depth is, therefore, of added importance, firstly because the suddenness and weight of the attack may be such that it will shatter the more forward defences which are exposed to concentrated artillery and mortar fire; and secondly because it tends to conceal the actual dispositions of the defenders, and so reduce losses.

To obtain the necessary depth a defensive system in position warfare should consist of:—

i. A forward or covering zone.
ii. A main zone.

2. The **main zone** will comprise the area in which the commander decides to fight out the battle and break the enemy's attack. It must, therefore, form the keystone of the whole defensive system; it must be organized in depth; and the natural advantages offered by the ground must be strengthened by the best and most carefully concealed obstacles and defensive works which can be constructed in the time available. The front line of the main zone will usually be the line in front of which it is intended to stop the enemy's attack.

3. The object of the garrison of the **forward zone** will be to keep a constant watch on the enemy by means of observation and patrols, to give warning of hostile attack, to defeat minor enterprises, and, in the event of a heavy attack, to absorb the first shock.

With this object the forward zone will usually be organized in an observation line of well concealed sentry groups supported by a chain of defended posts with a series of defended localities in rear, arranged in depth and affording each other mutual support. The forward units should be so disposed that they can cover by observation and fire the whole front of the sector.

The depth of the forward zone should be sufficient to protect the main zone from a preliminary bombardment by the enemy mortars.

4. The various posts and localities forming the framework of the defensive system should be connected up by continuous trenches as soon as possible : in each battalion sector there should be at least two continuous communication trenches from rear to front, one for down traffic and one for up traffic.

Though continuous trenches add to the labour of upkeep, they make the actual organization of the defence harder for the enemy to locate, especially from the air ; moreover, the existence of continuous trenches does much to prevent a feeling of isolation among the troops, and consequently preserves the morale of a defending force.

It must also be remembered that detached posts which adequately protect the intervening ground with their fire when observation is good are often unable to do so at night or in a mist or fog, and that it may then be necessary to establish connecting posts to prevent the enemy penetrating the position. Such posts can be conveniently located in specially prepared fire bays in continuous trenches, and can be withdrawn without detection by the enemy when the need for their employment ceases.

5. Early steps must be taken to construct an ample number of well-concealed and well-protected observation and intelligence posts and to provide them with alternative means of inter-communication. The construction of headquarters for infantry and artillery formation and units is also essential.

6. Everything possible should be done to provide cover for the garrison, first from the weather and secondly, as opportunity permits, from shelling. Successful defence, in position warfare, against modern bombardment can only be ensured by ample dug-out accommodation. Mined dug-outs or concrete block-houses form the best protection, but the former must have sufficient means of egress to allow the defenders to man their fire positions in time to meet an infantry assault.

7. The wiring of the forward and main zones must be done in accordance with a co-ordinated tactical plan so as to form as great an obstacle as possible to an enemy advance, but at the same time it must not prevent the advance of reinforcements or counter-attacking troops.

8. As soon as position warfare supervenes, forethought should be exercised as to what camouflage, if any, would facilitate the preparation of future offensive or defensive measures. The work decided upon should then be put in hand at once in order that by the time it is required the enemy may have become accustomed to its existence. The fall of the leaf requires consideration.

9. In a defensive system which extends over many miles of country it will be found that the physical features of the ground impose many serious difficulties which are not experienced in considering individual posts. The final selection must be a compromise between the most desirable and the best attainable as regards the system as a whole. If after the compromise has been effected the position is still unsatisfactory, the defences at the point of danger must be made in greater depth, or arrangements made so that its weakness is covered by artillery or machine-gun fire from the flanks or from the rear.

21. *Rear systems.*

1. To cover areas of great importance or where very heavy attacks are expected, it is necessary to construct defences in greater depth than that afforded by one defensive system in order that the enemy may be prevented from penetrating all organized defences in one rush or as the result of one offensive operation.

In such cases one or more rear systems of defence will be constructed at such a distance behind the system in front that the enemy will be forced to move his artillery and organize a fresh offensive.

Such rear systems will invariably be organized as described above with a main zone and a forward zone.

2. Switch systems may be constructed to connect one defensive system with those in rear in order to localize a break through by the enemy.

22. *Priority of work.*

The priority of work on the construction of all the various parts of the defensive system is a matter which will be decided by the commander according to the labour, time, and material likely to be available, but generally will be:—

- i. **Siting of weapons and O.Ps.**—artillery, machine guns and infantry posts, and marking their positions by pickets, tapes, or spit-locking the ground.
- ii. **Constructing observation posts and machine-gun positions** to get the greatest fire effect in the shortest possible time.
- iii. **Creating obstacles** so that the enemy may be hindered in his assault, and that the defender may shoot him while in difficulties.
- iv. **Digging fire positions** 3 feet deep so that the defender is protected and in a comfortable position to shoot the enemy.
- v. **Clearing and improving the field of fire** so that it may be difficult for the enemy to approach the position unseen and that it may be easy for the defender to shoot him in the open.
- vi. **Improving communications** by making gaps in hedges and improving roads and tracks so that it may be easy for the defender to transfer his troops from one part of the position to another, under cover, and difficult for the enemy to know the real strength at any point, and construction of signal communications.
- vii. **Completing the fire positions and connecting them up with shallow communication trenches** so that the enemy may find it difficult to know which are the fire positions in the air photographs. (*See* also Sec. **5** appendix X).
- viii. **Constructing dug-outs for headquarters and signals.**
- ix. **Completing the communication trenches.**
- x. **Constructing dug-outs for the protection of the garrison under the heaviest shell fire,** so that the greatest number of men may be available for counter-attack.

23. *Defended posts and localities.*

1. Defended posts and defended localities are the terms applied to self-contained defence works, whether they are detached defences protecting

some isolated point, or whether they are the groups of trenches or defended localities forming the framework of a complete defensive system.

In order to prevent the enemy locating the exact extent of such important defences, it is necessary that they should be extended or connected to neighbouring defences at the earliest possible opportunity, so that their identity may be merged in the general trench system. If this is not done isolated defended posts run grave risks of being obliterated by artillery fire, or are liable to an isolated attack.

2. **Defended posts** consist of a group of trenches or shell-holes suitable for a section or corresponding unit. They must be designed and sited to bring fire to bear in any required direction, especially to cover the ground between and in front of neighbouring posts. They must be wired, provided with observation posts for the garrison, and must be capable of all-round defence. Storage accommodation must be provided for water, ammunition of all sorts, rations and tools.

Defended posts may be situated in any portion of a defensive system, camouflaged from observation by the intricacies of the trench system in which they are located, or concealed by natural cover such as woods or hedges. They may often consist of short lengths of trench prepared for fire at junctions of fire and communication trenches. Machine-gun posts will normally be clear of the trench system and will depend on natural cover or artificial camouflage for concealment.

3. **Defended localities** consist of an area of ground organized for defence by a definite unit such as a platoon, company, or battalion. They will comprise groups of defended posts so sited as to cover all the ground to the front and flanks of the locality with fire and to cover all the ground between it and neighbouring localities. Each defended post within a locality must afford support to its neighbours, and be connected up by communication trenches on flanks and rear.

Accommodation for the reserve must be provided in the rear or on the flanks of defended localities, also for ammunition, water, &c., in addition to any shelters within the defended posts.

Obstacles must be provided in the front and flanks and where necessary in rear also, the necessary gaps being left for counter-attack, but these gaps must be concealed from direct observation.

24. *Villages.*

1. Each village will require special treatment according to its situation and extent. Whether a village should be included within the position or not must be decided on the spot, according to the lie of the ground and the advantages which will accrue to the enemy, if he is allowed to occupy it. Villages attract artillery fire and the effect of this is increased by the debris of the buildings; they also harbour gas. On the other hand, they provide cover and opportunities for a protracted resistance. The tactical advantages of holding a village, whether ruined or not, usually outweigh the disadvantages. Care must be taken that its defences are strongly linked up with those of adjacent localities, or the village will be isolated by the attackers advancing on both flanks and joining up again in rear of the defenders. Infantry defences should be provided outside the perimeter of the village, and full use must be

made of the concealment afforded by hedges, orchards, walls, &c., which generally abound on the outskirts to enfilade and surprise the attack. These defences should be connected by trenches to the cellars within the village. The roofs of cellars should be strengthened, and the cellars should be connected by subways, and provided with at least two entrances. The debris will provide opportunities for concealed Lewis gun positions. These should be so prepared as to cover the flanks of and all approaches to the defences (Plate 17).

2. A keep, or keeps, should be prepared on the outskirts of the village, ard towards the rear flanks, so as to assist in the re-capture of the defences by counter-attack.

25. *Woods.*

1. The inclusion of woods within a defensive position depends on their situation and extent. Woods harbour gas and, if heavily shelled with gas shell, they are untenable by attacker or defender. Woods of small extent may be converted into obstacles to break up the attack, by entangling their outer edges with wire, Sec. 48, 5, and siting trenches and machine-gun emplacements to flank them. If they are of large extent their inclusion within the position will be advisable, if possible, because (*a*) they afford cover for reserves, working parties, stores, tramways, &c.; (*b*) if the enemy is allowed to occupy them, they give cover for large concentrations of his troops; (*c*) they give cover from tank attack.

The system of defence should be designed for (i) the occupation of the wood; (ii) preventing the enemy from filtering into the wood when occupation of the trenches in it is impossible on account of gas.

2. The position of the trenches should be far enough from the front edge of the wood to prevent the enemy's artillery ranging on the front edge from affecting the garrison. Wide clearings will have to be made in order to obtain a field of fire, and trenches and machine-gun positions must be sited to flank these clearings (Plates 18 and 19); subsequently the trenches will be connected up into a continuous system. The entry of the enemy into the wood must be prevented by entangling the front edge and providing fire to flank it. In extensive woods, wide rides through the wood should also be cut and trenches and machine guns sited outside to enfilade them.

3. Passages within the wood must be cleared to assist communication and plenty of direction boards provided, so that any part of the defences can be reinforced and counter-attacks can be launched without losing direction.

26. *Shell-proof accommodation.*

1. The construction of shell-proof accommodation is described in Chapter XIV. The position of all dug-outs, shelters, &c., must be decided, so that work may be begun on them as early as possible.

2. The order of their construction will be decided by the commander under whose orders the defensive system is made, but generally will be :—

- i. Observation posts. Machine-gun emplacements. Brigade and battalion headquarters. Dressing stations.
- ii. Accommodation for the garrison.

27. *Notice boards and cables.*

1. To facilitate inter-communication throughout the position, there must be plenty of notice boards. These should be used to show :—

i. The names of the various sectors and trenches.
ii. The names of the defended posts and localities.
iii. The allotment of troops to the position.
[Lanterns should be provided for use at night.]

2. **Buried cable.**—To ensure signal communications throughout a position, cables should be buried in all situations exposed to shell fire. Whenever time permits the trench dug for the cables should be at least 6 feet deep.

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28. *Defence of camps and small posts against a badly armed enemy.*

1. When operating in mountainous country against an uncivilized enemy, who is likely to make night attacks, the leading consideration is to deny to **the enemy any ground from which he can bring effective fire to bear.** This precaution should never be neglected even when the country is to all appearances unoccupied.

When at rest protection is best afforded by the construction of a camp, as nearly as possible rectangular in shape with blunted corners, with defences arranged around its perimeter ; the three principal points to attend to are :—

i. An outer line of strong self-contained posts or piquets, placed so as to watch all dangerous approaches and to deny to the enemy all ground from which he could bring effective fire to bear on the camp by day or night.
ii. The defensive perimeter round the camp must be clearly defined by a breastwork or a good obstacle.
iii. All exits must be traversed and blocked with obstacles by night.

When the number of the defenders is insufficient to provide an all-round defence, the perimeter must be defended by flanking fire from works constructed with that object ; these works should be strengthened to the fullest extent possible in the time available and the interior defiladed from fire from all sides. If possible they should be surrounded with wire or as formidable an obstacle as possible.

The positions to be taken up in order to repel a night attack should be marked out as soon as possible after the force has reached camp. If there is only time to do this with a line of stones, it will give the defenders a definite line to occupy and hold on to.

For convenience in camping, troops should generally occupy the same relative positions each night ; but this convenience must be sacrificed to the arrangements necessary for defence, as it is very important that units should camp close to the ground which they would have to hold in case of attack.

In selecting a camp site attention must be paid to the water supply and its protection ; but the first consideration is a good position which naturally assists the defence against the most serious danger of a possible night attack.

Night latrines must be constructed inside the camp as no one is allowed outside the perimeter after dark.

2. When operating in bush or forest country the conditions closely resemble those of night operations.

When at rest vigilance by night is of the greatest importance; the defence of the camp should therefore be formed on the perimeter system, well guarded by obstacles with barbed wire, even a single strand of wire at a height of about 2 feet from the ground, a short way out from the perimeter of the camp, may be of the greatest use. It may, under certain circumstances, be advisable to apply this principle whenever the force halts in order to provide protection for the non-combatants and transport. These improvised defences may take the form of laagers or zarebas. Laagers are enclosures formed with the vehicles accompanying a force, supplemented by breastworks of pack saddles, stores, &c., and strengthened with trenches and abatis. Zarebas are enclosures fenced in by abatis of thorn bushes. It being most important to obtain a clear field of fire, the bush nearest the side of the camp must first be removed and arranged round the perimeter. Large trees should not be cut down as they afford less cover if left standing. Subsequently, tracks and hollows by which the enemy might approach may be filled with thorn scrub if time allows. Villages and old camping grounds should be avoided when selecting a site for a camp; the site should be up wind if near a village.

3. In local operations, hints as to the best design of defensive work may generally be got from the enemy, who will have evolved the types best suited to local materials, as well as to resist the form of attack and weapons which he will employ against us. Such types, when improved by the light of our own knowledge, modified to suit our weapons, and executed with the aid of good tools and engineering skill, will, as a rule, be suitable for our own use.

Plate 20 gives a type of a defended post, for use against an uncivilized enemy or when not exposed to artillery fire, where the block-houses are arranged to enfilade the lines of obstacles. South Africa produced corrugated iron and shingle blockhouses, surrounded by barbed wire; on the North-West Frontier of India, stone sangars are the rule (Plates 206 and 207); in the Soudan, breastworks of sand and thorn zarebas. Where railway stations have to be protected, blockhouses, stockades and splinter-proofs made of rails, and loopholed buildings will predominate.

29. *Field defences of a coast line.*

1. Works intended to resist the attack of a landing force will normally be sited, chiefly with a view to obtaining the best fire effect on the enemy while he is approaching in boats or in the act of landing; concealment of works from direct view of the enemy artillery is of secondary importance.

Generally speaking, the system of defence should be one of mutually supporting defended posts or localities by which troops may be economized and the risks attached to the provision of a number of detached works avoided. Any advanced trenches, which may be found necessary, must be definitely affiliated to a defended locality.

2. The organization of obstacles in the defended locality should be as described in Chapter VII, except that, in the case of coast defences, there is less objection to the obstacle round a defended locality being conspicuous.

3. The rules for siting machine-gun emplacements (Chapter VI) apply equally to this nature of defence works.

4. Special attention should be paid to establishing "Road blocking posts" to command the junctions of roads leading from the coast inland, to ensure that cyclists or other fast moving troops may be prevented from penetrating.

5. The development of a defensive system behind the defences on the coast line follows the principles laid down for positions inland.

6. The coast line may be classed under the following heads :—

i. Shingle beaches.
ii. Sand hills.
iii. Marshy shores with sea walls.
iv. Clay cliffs.
v. Cliffs of chalk or rock.
vi. Town fronts.

i. **Shingle beaches.**—The chief difficulties presented by these are :—

(*a*) The ever-varying nature of the beach under the action of the sea.
(*b*) The risk of casualties caused by the shingle under artillery or machine-gun fire.

A shifting beach involves constant changes in the field of fire, and considerable damage to, if not complete obliteration of defences and obstacles.

It must, therefore, be recognized that a position in this class of coast line calls for the highest order of vigilance and industry on the part of its garrison.

The defences should be of the simplest nature; trenches should be sited on the crest of the shingle bank; obstacles of a portable nature should be made and held in reserve to supplement the permanent obstacle at such places where it is most liable to damage by the action of the sea. Sandbags filled with sand or earth should be stored at definite places, to rectify small changes in the height of parapets and to give protection against flying pieces of shingle during a bombardment.

ii. **Sand hills.**—Positions among sand hills have disadvantages similar to those described for shingle beaches; trenches and obstacles, and sand drifts under the action of wind and sea are often totally effaced.

Sand hills by their peculiar irregularities afford valuable cover and concealment for the troops in occupation.

iii. Protection, in the form of shelters, dug-outs, &c., is required for the gun and personnel against their destruction by fire not specially directed against the position, such as area bombardments.

These conditions are difficult to reconcile, and the choice of site will be a compromise.

6. In mobile warfare there will seldom be time for elaborate emplacements, and guns will have to rely entirely on concealment for their protection.

7. In position warfare more elaborate emplacements can be provided. The greatest care must be exercised to prevent these being discovered, either in process of construction or when they are occupied.

In the forward area, owing to the difficulty of constructing and concealing strong works, the type of emplacement will be that which can be concealed most easily, and, owing to the likelihood of such positions being surrounded in the case of determined hostile attack, emplacements for all-round fire should be provided as described in Sec. **33** with a shell slit for the personnel (Plate **54**). Such an emplacement should be sited generally away from the trenches, to avoid the fire directed on the trenches. Access should be obtained by means of a carefully camouflaged trench or subway, to avoid overland tracks, which are very conspicuous from the air. If it is impossible to avoid making tracks, these should be continued beyond the position occupied to a dummy position, or to other trenches.

Further back, it will be possible to bring up special materials and construct strong emplacements. In most cases there will also be more cover, such as woods, hedges, buildings, in which the emplacements can be concealed. It will be possible, therefore, to construct splinter-proof emplacements (Plate **24**, Fig. 3), emplacements proof against light shells up to 4-inch, a shell-proof concrete emplacement, or an elaborate post connected by underground passages. Such a position must not be surrounded by belts of high wire which would show up the presence of the work from the air. If tactical wire is used (Sec. **34**) to force the enemy to advance in a particular direction and to bring him into the belt of machine-gun fire, machine-gun emplacements should not be placed in the angle of the wire, where the enemy is bound to suspect their presence; dummy emplacements may be made at these points if time permits; but the real emplacements should be sited in concealed ground to a flank or in rear.

8. In covered-in machine-gun emplacements, the firing of a few hundred rounds will cause the machine-gunners to be gassed and rendered unconscious by the carbon monoxide in the cordite fumes, released mainly from the muzzle, (but, to a small extent, from the breech also) unless good ventilation is provided.

Arrangements should also be made for ventilation at the back of the emplacement to create a through draught.

9. In most cases, positions for harassing fire, or for covering an attack, are chosen for one operation only, and need not be of such strength as is necessary for emplacements of a more permanent nature. These may consist of shell slits with open platforms for firing; or emplacements with light splinter-proof cover and wide loophole, such as that described in Sec. **32**.

In wet weather, when sustained fire is required, and when there is no opportunity for an elaborate work, a single sheet of galvanized iron, or other cover against rain, will be invaluable, and will greatly assist belt-filling.

31. *Concealment and drainage of emplacements.*

1. Many machine-gun emplacements depend for their security on concealment, and in all of them it is of first importance. The subject of concealment is dealt with in Appendix X.

The following paragraphs, however, show how a hasty machine-gun emplacement may be concealed, when no materials except those found locally are available.

2. A camouflage screen should be improvised, if possible, large enough to cover the whole emplacement. For an open emplacement this should be about 8 feet by 6 feet and can be made of strips of sandbags or canvas woven into wire netting. The netting should be fastened to two light poles, one at its centre and the other at one end. The screen is thrown over the emplacement with the pole at the centre over the rear edge of the platform. The other pole which is placed across the front of the emplacement can be raised when it is desired to fire (Plate 23, Fig. 2). The screen can be carried rolled round the poles.

3. Tracks are very conspicuous from the air. It is impossible to avoid making them, but they will not disclose the position of the emplacement if some procedure such as the following is adopted (Plate 24, Fig. 2).

Lead the team past the position chosen, to another 50 or 100 yards away. Dump stores there, and occupy this as a temporary position. Meanwhile, prepare the chosen position for occupation, using the tracks already made. When the proper position is completed and occupied, make all carrying parties, relief, &c., proceed past the position to the dump, round which tracks may be multiplied, and then move back carefully on their tracks to the occupied position. By this means the tracks will appear to lead past the position to the dump, in which dummy works can be made.

4. Excavated earth is conspicuous, especially from the air. Small excavations may be thrown into a shell-hole, but any considerable excavations should be removed in sandbags well away from the position and dumped round a dummy position. Approaches to a position should be constructed by sapping towards it so that the earth can be carried away along the sap.

5. Work must be concealed during its progress. For instance, if a platform or chamber has been dug out during the night, and it has not been possible to roof it over, a camouflage cover should be thrown over the work before daylight, and all tools and materials hidden under the cover.

6. Concealment of deliberate emplacements includes the concealing of all traces of work and occupation, and requires to be carefully planned on the lines laid down in Appendix X, before any work is started.

7. Drainage and revetment of machine-gun emplacements must be carried out on the same lines as the drainage and revetment of trenches described in Chapter IX.

32. *Hasty emplacements.*

1. These consist generally of an open emplacement of the dimensions shown on Plate 22 for open ground, or as shown on Plate 23, Figs. 4 and 5, when firing from banks or shell-holes.

The platform should be cut well into the bank or parapet, so that when covered the work will not appear to break the continuity of the bank. Cover for the personnel should be provided in the form of shell slits (Plate 54).

Where the ground is soft or unstable a T-base (Plate 26) must be placed in position on the platform.

When further time is available, a light roof can be built over the emplacement to give cover from weather. The roof will consist of about 2 sheets of corrugated iron or boarding, supported on 3-inch by 3-inch rafters, about 7 feet long, resting on light poles or 4-inch by 4-inch scantling about 4 feet long.

The inside of the emplacement should be revetted (Chapter IX), and a box or slit loophole will be required for the gun to fire through.

Only enough earth should be thrown on to the roof to hide it. If more than a few inches of earth are used, the emplacement will collapse when a shell bursts near it, the occupants will be buried and the gun put out of action.

2. Emplacements proof against light shell up to 4-inch can be made if one of the shelters described in Sec. 101 is available (Plate 24, Fig. 3), but it is generally better to rely on concealment for protection unless one of the emplacements described in Sec. 33 can be made.

The minimum dimensions of machine-gun emplacements are given on Plate 21.

The roof covering over the shelter should be :—

- i. Two feet thickness of earth next to roof.
- ii. A burster course of 1 foot to 1 foot 6 inches of hard material, *e.g.*, stones, brick, &c., in sandbags.
- iii. Enough earth for concealment.

A double course of logs wired together as used in Sec. 105, 4, is a useful addition.

A box loophole must be provided to fire through. The emplacement should be built as low in the ground as will admit of the required field of fire, otherwise it will form a very upstanding target.

3. Hasty emplacements will often be made in shell-holes. They are made on the lines indicated above, but should be as simple as possible, so that they may be concealed. Plate 23, Figs. 1, 2 and 3, shows a type of this kind of emplacement; in Fig. 3 the camouflage cover has been removed to show the framing of a light weather-proof roof.

Drainage in this case is best effected by carrying the water off to a deeper shell-hole, but the drain must be camouflaged.

33. *Deliberate emplacements.*

1. These may be classified under the following types :—

- i. Open emplacements.
- ii. Champagne type, which is also an open type, but which gives dug-out accommodation for the team in addition.
- iii. Reinforced concrete pill-box.

2. Open emplacements are the same as those already described, except that better provision can be made for the personnel.

These are required in forward areas, when it is impossible to construct either the Champagne type or the concrete emplacement. When constructed in isolated positions away from the trenches, the emplacement should be in the form used in the Champagne type. When located in a trench position, all that is required is a platform on which the gun mounting can stand. In both cases, the emplacement must be camouflaged from overhead observation.

3. **Champagne type emplacement.**—The emplacement itself (Plate 25) is merely a rectangular pit with revetted sides. A base is provided over a well, giving access to the dug-out below. Emplacements of this type are generally constructed in pairs communicating with a single dug-out. But, in order that the gun detachment may reach the emplacement without delay, the distance between the emplacements constructed in pairs should not exceed 35 yards.

This type of emplacement can only be used in localities where the water level admits of the construction of dug-outs. It is especially suitable for employment in an area normally liable to shell fire, more particularly in sites under direct observation from the enemy's observation posts, as it is invisible to ground observation and easily camouflaged from the air. When under direct observation, it is most undesirable that any splinter-proof cover should be provided, as it may disclose the emplacement and render it more difficult to remove casualties. A wounded man lying in the emplacement would seriously impede the work of the gun detachment and might block the exit from the dug-out, while the splinter-proof cover may be destroyed by shell fire and so render exit from the dug-out difficult or impossible.

In the area not normally liable to shell fire, Champagne emplacements are also most valuable, but their construction involves the use of much material and labour, and they should only be used to protect points of special tactical importance. They should be used in preference to concrete emplacements wherever possible.

Details of the T-base for the open machine-gun platform of a Champagne emplacement are shown on Plate 26.

4. The more permanent types of emplacements made of reinforced concrete are not dealt with in this book; they are described in Military Engineering, Vol. II (Defences).

CHAPTER VII

OBSTACLES

34. *Siting of obstacles.*

1. **Obstacles** are used to check or direct into certain channels the movements of enemy troops advancing to the attack and to hold them under fire as long as possible.

Obstacles are of two kinds :—

i. Tactical.
ii. Protective.

2. **Tactical obstacles** are intended to :—

i. Break up an enemy's attack formation.
ii. Restrict his power of manœuvre.
iii. Force his troops into positions in which they are more easily dealt with by fire, particularly machine-gun and anti-tank fire.

These obstacles are, therefore, sited in conjunction with the machine-gun and anti-tank defence (Plate 27).

They usually take the form of irregular blocks of entanglement, or wired areas, such as small woods and stream beds and anti-tank mines.

3. **Protective obstacles** are intended to hold the attackers under close rifle fire of the defenders. An obstacle will not stop the advance of a determined enemy unless the ground immediately in front of it is under effective fire from the defender.

They must be sited, therefore, in conjunction with the infantry defences. Enfilade being the most effective form of fire, the obstacles should be so sited that their outer edge is under enfilade fire from some portion of a fire trench.

They should be far enough from the trench to prevent the enemy from bombing the occupants with hand grenades, but not so far that they can be cut under cover of darkness or mist. The trace must be irregular not parallel to the trenches, but arranged in bold zig-zags, so that the obstacles are not destroyed by the same artillery barrage as the trenches. Generally, these conditions will be fulfilled by keeping the obstacle a minimum of 30 yards and a maximum of 100 yards from the trench, and they must not afford any cover to the enemy.

4. In spite of the great improvements introduced for the destruction of obstacles by artillery, experience shows that a well-sited and well-constructed obstacle has always some value even after the most severe bombardment.

5. Obstacles should be hidden from direct observation as far as possible in hollows and folds in the ground, behind and in hedges and ditches, below banks, or in brushwood, woods and crops.

In special cases it may be desirable to sink the obstacles in trenches, but labour is rarely available for this heavy work, and this method of concealment is usually confined to those portions of the front where breastworks have to be built—the borrow-pits are then laid out and dug with this end in view (Plate 28).

6. A sunken obstacle is of great value where defence against tank attack is required. A narrow sunken obstacle will not check the tank, but the tank will not be able to crush the wire to form a passage for the accompanying infantry. The obstacle will thus have the effect of breaking up the co-ordination of tanks and infantry and will go far towards checking the attack.

7. Obstacles should be difficult to remove or surmount, and are more effective if, in order to destroy them, the enemy is forced to carry special equipment. Special attention should be paid to their anchorages.

8. An obstacle covering a considerable area is less easily crossed or destroyed, and is less visible on air photographs than one made with the same quantity of material concentrated in a narrow belt. A uniform thickness and depth of obstacle should be avoided. Irregularity tends to break up an attack. Every opportunity should be taken to form pockets, in which the enemy will be held up under fire, by making obstacles along communication trenches (*see* Sec. 46).

35. *Gaps.*

1. The only gaps required in front line wire are a few small concealed exits for patrols; in rear lines, however, it is important to have plenty of well-marked gaps for counter-attacking troops to advance through, or in order that troops and guns retiring may not be hindered and delayed under the enemy's fire. All such gaps must be provided with knife rests, wire concertinas, &c., so that, in a withdrawal, they may be closed rapidly by the last troops to pass through them. If a gap is to be closed with knife rests, the ends of the entanglement on each side must be square, so that a complete block is effected (Plate 29). The knife rests must be securely anchored to the entanglement or to stout pickets driven into the ground, their inner ends being provided with loops of plain wire with which they can quickly be connected together when in position across the gap. Gaps for infantry should be provided about every 100 yards; to avoid additional gaps, they should coincide with communication trenches, where such exist. They should be zig-zagged through the obstacle zone, but should not be too complicated for a mounted man to pass.

2. Road gaps are extremely important, and must be carefully prepared for blocking (Plate 30), as they are the weakest points in the obstacle zone. Where they are numerous, the infantry gaps should be made to coincide with them as far as possible, except that, in the case of important main roads, it is better to make an infantry gap 20 to 30 yards to one side, so that the passage of infantry may not interfere with the traffic.

3. Where sufficient roads and tracks do not exist, special artillery gaps must be made every half-mile; they should go straight through the obstacle zone, should be well marked, and arrangements must be made to leave the trench undug opposite them or to bridge existing trenches; ramps into or out of trenches should not be made, as they become impassable in wet weather.

The obstacles must be protected from damage by guns and vehicles by rows of strong posts on each side of the gap.

4. Special gaps must be made for counter-attack, and no obstacle should be made without reference to the commander of the sector of defence.

5. All gaps should be well marked either by:—

i. "GAP" boards.
ii. Painting the posts at the sides of the gap white on the defender's side.

Every effort must be made, however, to conceal these gaps from hostile ground and air observation.

36. *Order of priority of work.*

1. The obstacles of a defensive position should be made in the following order of priority:—

i. Anti-tank obstacles where specially ordered.
ii. A continuous defensive obstacle will be made throughout, except for such gaps as are described above.
iii. This will be deepened and thickened, the depth and thickness being varied along different portions of the front.
iv. Tactical wire will be erected.

37. *Types of wire obstacles.*

1. The various forms of wire obstacles used in military operations are described below.

2. **Barbed wire obstacles** are at once the most effective and the most rapidly made.

The construction of wire obstacles is the duty of the troops holding the position to be defended, and, in order that this duty may be performed with efficiency and despatch, all ranks must be thoroughly trained in the use of the materials which may be available.

The following are the ordinary types of wire obstacle:—

i. Wire entanglement (French).
ii. Belts of concertinas.
iii. Double apron fence.
iv. Simple 4-strand fences for spider wire.

3. **Wire entanglement (French)** (concertina plain wire) is the most rapid form of entanglement. It must not be regarded as a permanent obstacle, but merely one that can be put up rapidly, and is capable of being strengthened afterwards. It is a standard to be adopted on emergency, and every man should be trained in its erection.

The pattern selected consists of two belts of wire entanglement coils one yard apart in the clear, with a horizontal barbed strand along the top of each belt; a trip wire windlassed on the front of the enemy belt; and loose wire thrown in between the belts.

The essence of a wire entanglement coil is rapidity, and its chief use is in a situation when rapidity is essential. The addition of loose wire and a trip wire certainly make the entanglement more efficient, and can be made as quickly as the coil itself can be erected (Plate 31, Figs. 1, 2).

4. **Concertina wire.**—A very rapid entanglement consisting of concertinas of barbed wire, fixed by pickets, and with one horizontal wire along the top of the pickets is shown on Plate **31**, Figs. 3 and 4. It has three rather serious disadvantages, in that it requires a good deal of preparation beforehand, is liable to become tangled in the dark and entails large carrying parties.

At least two rows of concertinas should be erected (one yard apart in the clear) to form an effective entanglement. One row is not sufficient.

5. **Double apron fence** consists of three horizontal strands on the fence, and three, including the trip wire, on each apron.

It has the following advantages :—

i. Effectiveness.
ii. Rapidity and simplicity of erection.
iii. Small carrying parties.
iv. Little preparation required beforehand.

Two or three rows of double apron fence laid out so that the distance between the rows is always varying, form a very efficient obstacle and is not easily destroyed by shell fire.

For very rapid work over long lengths, the back apron may be omitted ; the entanglement thus modified is sufficient to stop the most determined enemy attacks for a time, but it is easily damaged. The value of the entanglement lies chiefly in the front apron, which should never be omitted (Plate **32**).

Belts of double-apron fences form an excellent framework for a wide obstacle ; concertinas, or loose wire can be thrown in between the bays for thickening purposes (Plate **33**).

6. **Spider wire.**—The spider wire shown consists of a series of cattle fences placed according to Plate **34**, so as to divide up the ground into compartments. In laying out, care should be taken that not more than two or three fences meet at one point. The method of construction is the same as for the apron fence, omitting the aprons.

7. The visibility of wire obstacles from the air depends upon the length of time the wire has been erected, because, after a short time, the difference between the surface of the ground within the wire entanglement, which has been protected from traffic and the effects of the weather, will show as a dark shadow, and this shadow will be accentuated by the light lines across it wherever there is a track through the wire. It is not the wire entanglement which shows, but the difference in the surface, *e.g.*, increased length of grass, untrodden ploughed land, &c.

8. In eastern countries, where mirage occurs, the presence of a wire entanglement is frequently betrayed by its mirage at a height above the earth's surface.

38. *Preparations for rapid wiring.*

1. The rapidity of the work of making an obstacle depends very largely on careful preparation beforehand. The following points are essential :—

i. The line of entanglement must be taped ; if this is not done the party is sure to lose direction, the natural tendency being to come nearer and nearer to one's own trench.

ii. Dumps of wiring material should be made in convenient positions close to the work. This enables long lengths of wire to be erected in one night, and prevents the infliction of casualties by the enemy seeing progressive wiring being done night after night.

iii. Tapes should be laid from each of these dumps to the flank of the tasks concerned.

iv. All stores should be prepared for use and ready in man-loads.

2. **Wire-cutters.**—It is very seldom that there are enough wire-cutters to give a pair to every man in a wiring party. If stores have been prepared properly beforehand, there is no necessity for anybody, except the officers and N.C.Os., to have them, and the issue of wire-cutters should be strictly limited.

3. **Windlassing sticks.**—Every man of the wiring party should carry a short 2-foot stake or iron rod ($\frac{1}{2}$ inch diam.). These are necessary for :—

i. Screwing in pickets.
ii. Running out coils of barbed wire.
iii. Windlassing wire.

Jumping bars are only necessary when working in hard ground. They should be bound with whipcord, or a double thickness of canvas, to prevent noise.

4. **Handling of material.**—Rapidity in wiring depends very largely on the ability of the men to handle wire. Men must be trained to use it with confidence and not to be afraid of it. It is like a stinging nettle; if a man is not frightened of it, and treats it as if it were a rope, it will not hurt him. The best sappers and men, who have had long experience in wiring, never use gloves.

The plain wires securing a coil of barbed wire must be cut and a piece of sandbag or white cloth tied to the running end of the coil in order that there shall be no difficulty in finding it at night; the pieces of tin on the wooden drums must be broken off to prevent noise. All this should be done before material is taken forward for work.

Any temporary lashing that may be required for the transport or carrying of materials should be of twine, so that it can be cut easily in the dark. Binding wire must be reserved for permanent lashings. This is a most important point in the manufacture and use of barbed wire concertinas.

Wire should always be run off the reel from underneath, to save the hands of the man holding the coil.

5. **Screw pickets.**—The following rules should be adopted for all work with screw pickets, the standard sizes of which are given on Plate 35.

i. **Laying out pickets.**—Pickets must be laid so that the point of the screw faces the enemy, and indicates the spot at which the picket is to be screwed in.

ii. **Screwing in pickets.**—It is important that the eyes of all screw pickets should face the same way, as it is then much easier to fix the wire in the eyes. Pickets must be screwed in so that the eyes are parallel to the length of the entanglement and the cut end of the loop forming the top eye faces the direction from which the men are working, *i.e.*, the head of the task. It should be carefully explained to the men that the top eyes of some pickets are in the form of a loop and those of others terminate in an upright point. In these latter, the cut end of the loop has been straightened out, and in applying the above rule, it must be imagined that it has been bent down again.

6. **Fixing wire.**—For fixing wire on the screw pickets, the following rules should be adopted (Plate **36**) :—

i. Men fixing the wire must always work facing the enemy.
ii. Wire should be fixed to every second picket.
iii. To fix wire in the top eye of a long picket or the loop of an anchorage picket (Fig. 1) :—
Pull the standing end taut, pass wire over picket and slip the wire up into the eye; continue the upward movement in a circle coming down between the body of the eye and the point (the wire is now through the eye). Then take a turn with the running end round the picket below the eye, working clockwise.
iv. To fix wire in the lower eye when there is already a wire in the top eye (Fig. 2) :—
(*a*) If the eye is on the left of the picket pull the standing end taut, and force the wire down into the eye. Then take the bight on the running end, pass it round the picket, counter-clockwise, under the eye and then finish off by taking a turn with the bight on the running end.
(*b*) If the eye is on the right of the picket, the wire is slipped up into the eye and the bight on the running end passed round the picket above the eye.
v. All horizontal wires of an apron must be fixed to the diagonal stays by windlassing (Fig. 3).

Note.—Some pickets may be found in which the eyes are bent the reverse way to that shown in Plate **36**; in this case the above instructions must be reversed.

If these rules are carried out, the wire will be firmly fixed in the eye and cannot slip up or down the post; also, if one bay is cut, the wire in the bays on either side remains taut and does not slip through the eyes. They apply whichever way the wirers are working—from right to left or left to right.

These methods of fixing wire are found to be far more satisfactory and rapid than employing short lengths of plain wire. The latter method is slow, and the plain wire almost invariably runs short, or is forgotten or lost at night.

Plate **37** shows the method of fixing wire to wooden posts.

7. **Holdfasts.**—Screw anchorage pickets must be screwed in the direction of the stay wire or they will be drawn in the direction of the strain. In sound earth "Hair-pins" or wire entanglement coil staples can be used in lieu.

39. *Drills for making wire obstacles.*

1. **Drills.—Many drills have been evolved by which long lengths of good wire entanglement can be erected rapidly by well-trained squads.** In practice, such squads are seldom available.

Any drill which is to be of value must be so designed that :—

i. It is easily carried out by partially trained or untrained men in the dark or under fire.

ii. Casualties can be replaced as they occur, without disorganization of work or duties.

The drill must, therefore, be as simple as possible, the ideal solution being "one man one job."

It may be found sometimes that this is not possible, owing to the necessity for keeping the party small enough to be supplied by a platoon under normal front-line conditions.

The following additional points have been considered in working out the drill given below :—

i. Men should work in pairs or groups of three.

ii. No one group should ever cross another in the course of its work.

iii All groups should work in the same direction, from one flank of the task towards the other flank.

iv. Groups should work at intervals so that the men are not bunched.

v. The pattern of the entanglement and method of erecting should be such that no group has to step over the wire previously erected by another group.

2. Drill for Double Apron Fence.

(9 horizontal wires).

Party : 1 N.C.O. and 10 men (no more are likely to be available from a platoon holding a defended post).

Fall in and number : 1 to 10.

Stores for 50 yards double apron fence.

20 long screw pickets	5
40 short screw pickets	5
7 coils of barbed wire (approximately 130 yards each)... ...	7
Man loads	17

First Duty (Stores).

1, 2, 3, 4, 5, 6, 7, 8, 9, 10 ... ... All numbers carry out all stores and dump at the end of task (two journeys).

Second Duty (Pickets).

1, 2, 3, 4, 5, long picket Nos. ... 1, 2, screw in long pickets three paces apart (7 ft. 6 in.) along the tape, 3, 4 and 5 lay out pickets in position and then help 1 and 2 to screw them in.

6, 7, 8, 9, 10, short picket Nos. ... 6, 7, screw in short pickets opposite the intervals between long pickets, and 6 ft. from the fence on each side, 8, 9 and 10 lay out pickets in position and then help 6 and 7 to screw them in.

THIRD DUTY (WIRE).

1, 2, 3, 4, 5, 6, horizontal wire Nos.	1 and 2, 3 and 4, 5 and 6, run out and secure three horizontal fence wires, then three horizontal front apron wires, then three horizontal back apron wires.
7, 8, 9, 10	7 and 8, 9 and 10, run out and secure the front diagonal wire and rear diagonal wire, respectively, commencing at the top of the first picket and finishing at the top of the last picket.

Note 1.—9 and 10 must give the horizontal fence wire numbers a start.

Note 2.—When each pair has reached the end of the line and secured the wire to the last picket, the N.C.O. will cut the wires with his wire-cutter. The pair will then return with the remaining wire on the reel to the near end and either carry on with their next task or deposit the coil in the dump for other numbers to use.

Note 3.—Time will be saved in the actual construction of the entanglement if the wire can be specially coiled beforehand into two coils 130 yards long and 9 half-coils each 65 yards long.

3. Where circumstances make it advisable for the men to work only on the side of the wire away from the enemy, the following should be substituted for the "Third Duty":—

1, 2, 3, 4	1, 2, 3 and 4, run out and secure front diagonal wire.
5, 6, 7, 8, 9, 10	5 and 6, 7 and 8, 9 and 10, run out and secure three horizontal wires on front apron.
1, 2, 3, 4, 5, 6	1 and 2, 3 and 4, 5 and 6, run out and secure three horizontal wires on fence.
7, 8, 9, 10	7, 8, 9, 10 run out and secure rear diagonal wire.
1, 2, 3, 4, 5, 6, ...	1 and 2, 3 and 4, 5 and 6, run out and secure three horizontal wires on rear apron.

40. *Methods of thickening a framework of apron fence obstacles.*

1. Various means of thickening a framework of apron fences are shown on Plate **33**. The method of preparing the material is given below.

2. **Barbed wire concertinas.**—Draw a circle 4 feet in diameter. Place nine posts equally spaced round this circle and drive them in, leaving a height of 5 feet above ground; angle steel pickets are better than wooden ones. Make a framework to fit over the top of pickets to prevent them from being forced inwards (Plate **33**). One coil is required for each concertina with short lengths of plain wire for binding. Three men make the concertina. No. 1 works inside the framework, Nos. 2 and 3 run out the coil.

Construction :—

i. Take two complete turns round the nine posts with No. 12 plain wire or four turns with No. 14 wire, and bind these turns together at each interval between the posts so as to form a secure end for pulling the concertina out.

ii. Fasten the end of the barbed wire to the plain wire and take 24 turns round the posts in a spiral form, binding two consecutive turns together at every other interval.

iii. Make two turns with plain wire and make fast as in i. above.

The time required to make one concertina is 20 minutes.

The best method of preparing a concertina for carrying is shown on Plate **38**. The 5-foot laths must be lashed together tightly with twine. A man must use both hands to pull the concertina out, holding the plain wire turns at the end of the spiral.

A barbed wire concertina can be extended to a length of 18 to 20 feet, and requires to be pegged down with staples or hair-pins in the same way as wire entanglement coils. To stiffen it, screw pickets can be used (as for wire entanglement coils); the pickets are screwed in first of all, at 3 yards interval; the concertina is then extended, dropped over the pickets and pegged down.

3. **Method of preparing loose wire.**—The task of throwing loose wire into an entanglement from a coil is a long and tedious one. It is made very much easier and quicker if the wire is coiled in a spiral form beforehand.

To do this, drive in two 3-foot stakes, 3 feet apart, and two more at right angles to them 1 foot 6 inches apart. Then wind 100 yards of barbed wire round this diamond shaped framework, gradually working it up the stakes in a spiral. Finally tie the spiral together in four places with twine and take it off the stakes.

A spiral thus made can easily be carried by a man on his shoulder in a trench.

To use it as loose wire, cut the bindings, carry the spiral on the left arm and walk along, throwing two or three coils at a time into the entanglement.

One spiral supplies enough loose wire for a bay 2 yards wide and 25 yards long. It takes two men 5 minutes to make one of these spirals, and a man can throw it in as loose wire almost as fast as he can walk. If spirals are needed in large quantities, a winch is useful and saves time and labour.

If time and opportunity to make spirals are lacking, loose wire can be placed as follows :—Uncoil a 50-yard length on the ground, cut it, pick it up with a long forked stick, twisting it to and fro, and throw it on the entanglement. Press it well down and secure it to the wires already in position by windlassing.

4. **Knife rests.**—Forms of knife rests are shown in Plate **39**. They can be readily improvised. Sufficient lengths of the distance piece must be left at each end for carrying.

41. *Man loads.*

The following are found to be convenient man loads of various materials used to wire entanglements. The numbers have been worked out not only as fair loads for the average infantryman, but also that they may be in the proportions required for wiring, and therefore do not necessarily agree with Appendix VI.

A mule will carry about 4 man-loads.

Material.	No.	Average total weight.
		lbs.
Pickets, screw, long (5 feet 7 inches long with 4 eyes)	4	24
" " short (2 feet 1½ inches long with 2 eyes for anchorages)	8	22
Pickets, angle, long (6 feet long)	2	28
" " medium (3 feet 6 inches long)	4	36
" " short (2 feet long)	8	36
Pickets, brushwood, long (5 feet long, 3 inches to 4 inches diameter) ...	4	36
" " short (2 feet 6 inches long, 2½ inches to 3 inches diameter)	8	24
Wire, barbed, No. 12½ S.W.G. (130-yard coils)	1	32
" " No. 14 S.W.G. (176-yard coils)	1	32
Wire entanglement (French), coils	2	39
Concertinas	1	40

42. *Miscellaneous obstacles.*

1. A **tree entanglement** may be formed by cutting trees, brushwood, the strongest timber in overgrown hedges, &c., nearly through, about 3 feet above the ground, bringing the upper parts down to the ground and interlacing and securing them by pickets. Large trees thus treated form obstacles specially useful for blocking roads; the ends of thick branches should be pointed, and all weak places strengthened by ordinary abatis.

This is the best method of entangling the edge of a wood to prevent the enemy troops from rushing trenches behind it. Vines or hops woven together with their tops picketed to the ground form good entanglements.

The tools and time required for this class of obstacle vary according to the material of which it is formed. Axes, saws, billhooks, mallets and ropes are generally necessary.

In scrub or wooded countries an abatis of thorn bushes is a most effective obstacle against a savage enemy, especially round a perimeter camp. A disadvantage of abatis is that it is difficult to see through and this may mask the defender's fire, but this can be got over by placing the abatis so as to enable enfilade fire to be brought to bear along its outside faces.

2. **Barricades** are used to close streets, roads and bridges against a rush of enemy troops, armoured cars, &c.

As a rule, they should not close the road completely, but should be made in two overlapping portions or placed where a house standing back from the general line allows a passage round them (Plate 40, Fig. 1).

They will rarely be prepared as defensive parapets, their defence being effected by machine guns and rifle fire from hidden positions in front and in rear of the barricade (Plate 40, Fig. 2).

They can be made of nearly any material, but have the disadvantage of being opaque and thus giving the enemy cover from view.

A useful form of movable barricade against rushes by armoured cars is shown on Plate **40**, Fig. 3. Carts filled with stones, &c., have been used for the same purpose. They are kept in a side road, until required, when they are run into place.

3. A method of converting the railing on an esplanade wall into an obstacle against an attempted landing (Sec. **29**) is shown on Plate **41**.

4. **Inundations** can be made in the broad flat valleys of slow running rivers or streams by damming the stream. It is important to do this at points where the greatest effect can be produced with the least labour, *e.g.*, bridges.

If the valley is a shelled area it is rapidly made an impassable obstacle, for even if the water is only 6 inches above ground level it prevents the troops from avoiding the shell-holes. Loose barbed wire adds to their difficulties.

5. **Mines.**—Surface mines are used to inflict casualties on the enemy and lower his morale, and are usually some form of trap set off by pulling a string or cutting a wire. They are dealt with in Chapter XVII.

6. **Tank obstacles.**—Tank mines are the best obstacle against tanks. These would be provided and laid by the engineers of the formation responsible, and are dealt with in Military Engineering, Vol. IV.

A tank cannot surmount an obstacle with a nearly vertical face of 6 feet height; a ditch 10 feet wide and 6 feet deep is an effective obstacle, but the labour of making this is generally prohibitive.

It may happen that it is possible to scarp a road bank on a hill side in such a way as to form an obstacle which may hold up a tank attack under fire.

If time permits and labour is available, concrete blocks about 2 feet cube placed at 5 feet intervals, and tank traps (*i.e.*, pits 10 feet wide and 6 feet deep, covered over with light material) are effective obstacles.

7. **The illumination of obstacles** may be effected by the use of Véry lights and parachute rockets.

8. **Passage of obstacles.**—The destruction of obstacles such as abatis, wire entanglements, and barricades, prior to an assault by the infantry, is usually undertaken by the artillery with fire from guns, howitzers, and mortars with instantaneous fuze.

For raids the Bangalore torpedo has been found effective. The Bangalore torpedo is an explosive charge contained in a cylindrical case—the effect of the charge is to make a gap in the obstacle the length of the torpedo. Details of this torpedo are given in Sec. **120**, 3.

The passage of other obstacles, such as inundations, streams, ditches and ravines, is dealt with in Chapter XII under Bridging, and in Military Engineering, Vol. III.

CHAPTER VIII

THE SITING OF TRENCHES

43. *Reconnaissance.*

1. The siting of trenches is an operation which can be carried out satisfactorily when conditions allow of facilities for reconnaissance before work is commenced.

2. When defensive action in mobile warfare crystallizes into position warfare, the front system of trenches of either side register the mean high water mark of the attack, and are actually the places at which the foremost fighters have dug themselves in. The conditions allow of little latitude for siting of these trenches. The individual pits, convenient shell-holes, remains of hedges, debris of walls and buildings, are gradually merged into a system, until at last there is a semblance of a continuous line.

3. Behind this, if the circumstances permit and demand it, other lines or systems will be developed, where preliminary reconnaissance can be made. Their reconnaissance will be carried out according to the principles given in F.S.R., Vol. II, and will determine the general siting of the whole defensive system, which is described in detail in Chapter V.

44. *The detailed siting of infantry trenches.*

1. The detailed siting of infantry trenches requires a close study of the ground in order to make the best use of its possibilities. It is rarely feasible to grasp the whole of the possibilities of the features of the ground at the first attempt at siting the trenches, and the junctions of the different sectors of the defensive system will demand adjustments of the siting as first determined. Unless these adjustments are made before the trenches are traced (Sec. **13**), time and labour will be wasted; the labour will become disheartened and the completion of the trenches will be delayed.

When the conditions admit, the siting should be marked out with small flags, so as to allow of alteration without waste of time and labour, and the position of the flags should be determined finally before the tracing parties are set to work.

2. The infantry trenches must be sited so as to secure the observation posts of the position from capture by the enemy in a minor operation (Plate **42**, Figs. 1 and 3), and must cover positions from which the artillery and machine guns can break up an enemy attack and can afford adequate support to the infantry manning the trenches.

3. Artillery and machine guns form the framework of any defensive system. Infantry trenches must, therefore, be sited in close co-operation with the artillery and machine-gun defence and in such a manner as not to interfere with their field of fire. Anti-tank defences must also be fully considered. Suitably placed obstacles (Chapter VII) will force the attacker to adopt lines of approach which can be swept by artillery and machine-gun fire.

4. The guiding principles in the siting and design of fire-trenches are :—

   i. *Field of fire.*—A fire-trench should admit of the fullest possible development of the power of the weapons used by the defenders, but an extensive field of fire is by no means always the chief consideration.

   ii. *Protection.*—A fire-trench should restrict to the fullest possible extent the power and effect of the weapons of the attackers.

   iii. *Mutual support.*

5. **Field of fire.**—The ground which a system of fire-trenches is intended to cover must be swept by fire, either frontal or enfilade as the local conditions permit.

The distance within which a determined defence can stop an equally determined attack has been sensibly reduced by the improvements in the rate of fire and accuracy of rifles, machine guns and artillery. A minimum field of fire of 100 to 150 yards is accepted as satisfactory on positions, which it is intended to hold to the last, provided that artillery observation of the enemy's advance can be obtained from some points within the position.

In positions which are lightly held, such as outpost positions, if the conditions admit of any choice of site, a field of fire of from 400 to 600 yards should be aimed at. When deciding the field of fire from a proposed trench, the eye should be at the level of the top of the parapet.

Enfilade fire is most demoralizing to the attacker and most heartening to the defender, since the attacker comes under the fire of a defender with whom he is unable to close. The alignment of the trenches, therefore, should be very irregular, following the lie of the ground, forming alternate bastions and re-entrants, running forward on spurs and back in the valleys.

In mountainous or hilly country where slopes are steep, it will often be impossible for trenches to be sited so as to cover the ground to their immediate front ; in such cases the front of a trench must be covered by the fire from trenches on one or both flanks.

6. **Protection.**—Protection is best provided by concealment of the trenches, which in addition affords opportunities for surprise.

Concealment of trenches.—The improvement in fire-arms has necessitated more attention being paid to concealment of trenches, and although systems of trenches cannot now be hidden from air photography, they can be concealed, to a great extent, from direct observation by correct design and careful siting, so that an enemy can be kept in doubt as to the portions of the position which are occupied, and the strength in which they are held.

In design, the first step towards this was the abolition of the high command parapet, and the introduction of the deep fire trench with low command. Later experience has confirmed this change of design, even though the field of fire is more readily affected by minor undulations, because the rifle or machine gun is brought nearer the ground.

In siting, trenches are concealed by using folds in the ground and natural cover, such as hedges, banks, crops, &c. Even when the general line to be held is on a forward slope, much may be done to hide individual lengths of trench by siting them on the reverse slopes of undulations of ground, while still retaining the requisite field of fire and observation of the enemy.

From the point of view of concealment the worst position for earthworks is on the sky line, or with a distant background when seen from the attacker's observation posts. Trenches when placed even well down the slope of a hill will sometimes be found to be on the sky line, when viewed from the enemy's position (Plate 42, Fig. 2). **Whenever possible, therefore, siting must be examined from the enemy's point of view.**

When it is not possible to conceal earthworks they may be sited so that it is difficult for the enemy to observe the burst of his shells, as, for instance, on a low ridge with depressions to front and rear. These depressions will render it difficult for the enemy's ground observers to see where his shells fall.

7. **Mutual support.**—Fire-trenches must be sited so that they give mutual support. By this means, dead ground in front of one trench may be covered by one to a flank; enfilade fire can be obtained and, should any portion of the position be penetrated, the enemy may be prevented from reinforcing or exploiting the penetration.

8. **Drainage.**—Unless tactical conditions make it imperative, trenches should never be sited on ground likely to be flooded or in which the water level is liable to rise and render the trenches waterlogged. Breastworks have to be constructed in such places, but they possess many disadvantages (*see* Sec. 61).

45. *Forward and reverse slope positions.*

1. A forward slope position is one in which the trenches are on the slope of a hill nearest to the enemy so sited as to give the defender, from his trenches, a clear uninterrupted view of the enemy's trenches and the ground over which he must advance to the attack.

A reverse slope position is on the side of a hill farthest from the enemy and the defender's trenches are hidden by the contour of the ground from direct ground observation by the enemy (Plate 42, Fig. 1). Before a reverse slope position can safely be taken up, positions in rear or on the flanks must be found, from which the enemy advance can be observed.

It is impossible to find a position of any extent in which the slopes are even and uniform. All irregularities of ground present either a convex or a concave surface. These irregularities offer temptations either of going too far forward on a convex slope for a good view, or of drawing back too much on a concave slope to escape enemy observation, with the result that pronounced and therefore inconvenient salients are formed in the general lines of a position.

In order to avoid these salients and to make use of those features of the ground which offer the best facilities for defence, it may be necessary to site trenches in one place on a forward slope and in another on a reverse slope.

Therefore possibilities of both forward and reverse slopes must be considered.

2. **Forward slope positions.**—When trenches can be placed some way down the forward slope, it is generally easy to site them so as to protect observation posts, giving a good view of the enemy's trenches and the ground over which he must advance to the attack, but such trenches

must not be sited so far down the slope that they cannot be supported by artillery within effective range (Plate 42, Fig. 3). Also, when siting the front line, the position of support and reserve trenches must be considered. These trenches may be concealed from ground observation by the enemy by skilful use of minor undulations. When these conditions can be fulfilled and adequate communication between the trenches is provided, a position well down a forward slope is generally difficult to attack successfully.

There is a natural tendency to place trenches on high ground: such ground is not always the best. The advantages of high ground are, that the defender instinctively feels greater confidence, that communications are more easily concealed, that a better view of the enemy is obtained and that trenches, generally, are more easily drained. The disadvantages are that the defender's fire is more plunging than grazing, that the position of the trenches can be located more easily by the enemy when at a distance, that the assaulting infantry can be supported by the attacker's guns until a later moment, and that the enemy may work round the position and take it in flank and reverse.

3. **Reverse slope positions.**—When the slopes of the summit of a hill are gradual on the defender's side and the crest is broad, it may be necessary to place the trenches of the main zone some distance on that side of the crest. Under these conditions the crest of the hill will screen the trenches from ground observation by the enemy's artillery observers, but it is often difficult to provide the necessary field of fire and observation, and, should the enemy succeed in establishing himself between the crest of the hill and the defender's trenches, the advantage will lie, generally, with the enemy. The defender must have observation over the front slopes either from some position in rear, or from the flanks, and he must be able to bring effective fire on them.

46. *Communications and drainage.*

1. **Communication trenches** require as careful siting as fire trenches; they must not be laid out in stereotyped zig-zags and waves. They should be sited with the main object of affording concealed approaches and whenever possible, provided concealment is not sacrificed, they should give a reasonable field of fire to both sides. In any case, selected portions should be sited as fire trenches for flank defence. In this way pockets are formed in which an enemy attack penetrating the front line can be held up under fire until he can be annihilated by artillery fire or be dealt with by counter-attack. A complicated system of communication trenches should be avoided. They should provide one "up" and one "down" route for each company front between the front line and company reserve trenches, and one "up" and one "down" route for each battalion front between the company reserve trenches of the forward companies and battalion reserve trenches. One communication trench for each battalion up to the battalion reserve trenches will usually suffice.

2. **Drainage.**—Drains must be dug at the same time as trenches which they are to serve, so that it is necessary to consider the drainage plan when the trenches are sited. The slopes of the ground must be used to carry off the water to the natural drainage channels. Sumps should be necessary only in very flat country, and should be considered a last resort, when no modification of the siting will induce a natural flow.

47. *Considerations summarized.*

To sum up:—

i. Infantry trenches must be sited so as to cover artillery observation posts and battery positions, and so as not to interfere with the siting of machine-gun positions. They should, whenever possible, be protected by natural tank obstacles or in positions inaccessible to tank attack.

ii. A field of fire of 100 yards in front of each fire trench is necessary. When deciding this, the eye should be at the level of the top of the parapet.

iii. Enfilade fire is the most effective form of fire. Provide for it, remembering that a man armed with a rifle always fires at right angles to his parapet.

iv. Trenches on a forward slope must be so sited as to admit of ground in front of them being covered by the fire of the artillery.

v. The artillery must be able to get good observation and field of fire over the ground immediately in front of the fire trenches. Where this can be obtained from higher ground, in rear or from flank positions in the neighbourhood, advantage should be taken of reverse slopes in siting trenches so that, while the enemy is under observation, the defending troops are concealed from view.

vi. Communication trenches should be sited so as to form adequate but simple means of communication between the different fire positions and also to provide for flank defence.

vii. The effect of gas on fire and communication trenches must be closely considered.

viii. Drainage must be considered when siting trenches.

48. *Improving and clearing the field of fire.*

1. **Preparation of the foreground.**—In order to comply with the condition that a field of fire of at least 100 yards is required, it will often be found even in the most open countries, that a certain amount of clearing will have to be done.

This must be performed in such a way as to give no assistance to the attackers in their advance or in the use of their weapons. At the same time the possibility of adapting and improving any existing cover for the use of defenders should be borne in mind. Natural obstacles, which may be left, should be such as will not interfere with counter-attack troops or screen the enemy from fire. It should be remembered that concealment of the works of the defence is a vital factor in holding them against an enemy equipped with powerful artillery.

It will be advisable first to improve the field of fire near the position and work forward as time permits; but in case of a delaying action where fire effect at long ranges is required early, it is better to prepare for bringing fire to bear upon points at some distance from the position.

Before commencing any work, a rough estimate of the time, labour and tools required should be made so that the result aimed at may not be too ambitious. A field of fire only partially cleared may provide more effective cover than in its original state.

When clearing the foreground, it is frequently of advantage to leave a natural screen, concealing some portion of the position from the enemy's view. For instance, a line of trees may be left standing when clearing a wood; these will obstruct the enemy's view, whilst offering very little hindrance to the fire of the defenders.

Hedges impede the attack and can be converted into very effective obstacles. They should seldom be entirely cleared. Thick hedges should be thinned and entangled with barbed wire, gaps being cut at intervals to give a clear view.

2. **Trees.**—Large scattered trees give less cover when standing than when cut down, and may sometimes be useful as range marks. It should not be forgotten, however, that they may act also as range marks to the enemy. Unless they can be removed, only their lower branches should be trimmed off.

3. **Brushwood.**—Thick brushwood, especially in the case of some tropical growths, forms a very effective obstacle. In place of clearing it altogether, portions may be left to deny special points to an enemy, to break up his attack, and to compel him to adopt particular lines of advance.

Thin brushwood, however, unless cut and entangled, can generally be traversed easily by infantry without great loss of order, and if left standing may serve to screen an advance.

4. **Walls.**—Walls must be dealt with on the same principles as hedges. When it is required to demolish them, they can frequently be knocked down by a party of a dozen or more men, using a trunk of a tree, or a rail, as a battering ram.

Low buildings may be treated similarly. Houses and buildings should be burnt and left standing—so that there may be no access to the upper floors, which might be useful as observation posts; the entrance to the cellars must be blocked. The debris of a house or wall forms very good cover for a machine-gun emplacement.

If it is decided to blow them down, it must be remembered that the amount of explosive carried in the field is limited, and that the debris of the buildings will be more valuable as concealment and protection for the cellars against artillery fire than the buildings themselves.

5. **Woods and orchards.**—It is rarely possible to undertake the wholesale clearing of a wood—the work is usually restricted to the thinning of the undergrowth and removal of lower branches—arrangements being made to deal with the enemy just after he has emerged from the wood by holding him under fire with suitable obstacles.

Wide rides may be cut if time permits. These rides are like peep-holes cut through the wall of a house into the rooms beyond. The rides combined with a wire obstacle run obliquely through the wood may often assist in recording and checking the progress of the enemy (Plate 43, Fig. 1).

If the wood is heavily indented on the side of the defence, the indentation may be exaggerated; by this means the enemy advancing through the wood may be induced to "bunch" at the salients "A" before emerging, and losses can be inflicted if the defenders are alert (Plate 43, Fig. 2).

6. **Crops.**—Grain crops must be treated in the same way as woods. There is never time to clear the ground entirely, but with the help of cutting machines, rides and indentations are quickly made.

Clearing crops with sickles and scythes is a very slow process, and requires skilled reapers.

7. Range marks should be provided, and should be placed on that side of large trees, houses, banks, &c., which is only visible to the defence. The simplest arrangement consists of one white object for each 100 yards of range; 500 yards may be denoted by the sign V, made with two boards, poles, &c., and 1,000 yards by the sign X, intermediate hundreds being indicated by single objects in addition, as above described.

Every soldier should, in addition, know the ranges to points under fire from his post, which are likely to be traversed by the enemy. These points should not be selected merely because they are prominent.

CHAPTER IX

DETAILS OF TRENCHES, FIRE POSITIONS, AND TRENCH ACCESSORIES

49. *General remarks.*

1. All fire positions, trenches and works intended for occupation by troops must be designed to give the most efficient protection possible against the effect of the enemy's projectiles from all directions. This protection is afforded by :—

- i. A bullet-proof parapet against frontal and oblique fire.
- ii. Traverses, against enfilade fire, and to limit the effects of shells which burst directly in the trench.
- iii. Parados, or parapets on the rear side of the work, against reverse fire and the back blast from high explosive shells and bombs fitted with instantaneous fuze.
- iv. Trenches not less than 6 feet 9 inches wide to minimize the risk of men being buried by collapse of sides under bombardment and not less than 6 feet deep to allow men to move about and stand up without risk of being hit by bullets. The standard trench is only 6 feet 2 inches deep (Plate **48**, Fig. 3).
- v. Shelters and dug-outs, which are described in Chapter XIV.

2. The efficiency of any design depends upon the combination of trace and profile to meet the tactical and physical conditions of the ground and the probable nature of the enemy's attack.

The trace of a work is the general plan on the ground, the profile is its cross section.

50. *Fire trenches.*

1. The **trace** must not contain long straight lengths of open trench, which will be exposed to enfilade fire, except where protection against bombing is necessary (*see* Sec **51**). The length of any one bay should, therefore, not exceed 30 feet. In special circumstances where a trench system has to be completed quickly the length may be increased to 50 feet.

Traverses must not be less than 15 feet thick, and they must overlap the rear edge of the fire bay by not less than 5 feet at ground level, so that in trenches of the trace shown on Plate **44**, Fig. 1, the fire bay must be at least 27 feet long, viz. :—15 feet (width of rear traverse) plus 12 feet (width of two communication trenches).

Besides being irregular in itself, the general line of the trace must be laid out in bold curves, so as to increase the enemy's difficulty in organizing bombardments and barrage fire.

A berm 18 inches wide should be left clear from the top edge of the trench to the toe of the parapet or parados, to prevent the collapse of the sides of the trench from the weight of the earth. In the case of communication trenches, a berm of at least 2 feet 6 inches width should be left, in the first place.

2. To trace and dig a trench quickly :—

- i. Site fire bays 10 yards long and about 10 yards apart.
- ii. Connect up ends of fire bays behind a traverse 4 yards deep.
- iii. In throwing up earth, leave a berm of one yard on either side.

3. The forms of trace in general use are :—

i. The "square" trace which consists of a series of fire bays separated by traverses at right angles to the fire bays (Plate 44, Fig. 1).

This type gives the best protection, for all the angles are well closed in, but it is slightly extravagant in time and labour.

ii. The "bastion" trace (Plate 44, Fig. 2) is similar to the square trace, but the sides of traverse are set at about 135 degrees with the fire bays. This type gives good protection but is more open at the angles ; it does not involve quite so much work over a given length of line, and is easier for traffic and fire control. This trace can advantageously be used for communication trenches, especially where these are required to be prepared for use as fire trenches.

iii. The "zig-zag" trace (Plate 45, Fig. 1) is a number of fire bays laid out in a series of zig-zag, of which no angle should be greater than 135 degrees.

This trace is simple to lay out, quickly constructed, but depends for protection on its irregularity of line—for there are no traverses.

Some alternative traces based on combinations of the above are shown in Plate 45, Fig. 2, and Plate 46, Figs. 1, 2 and 3. The dog-leg trace (Plate 47, Figs. 1 and 2) is very useful for a continuous line across a valley with steep sides. A normal type of fire trench would be a combination of the "square" trace and the "bastion" trace.

4. The **profile** or section of a trench must be designed so that the trench provides :—

i. A position from which men firing can use their rifles effectively.

ii. A passage or communication trench, which should be deep enough and wide enough to allow of the safe passage of stretcher-bearers, &c.

5. A typical section with the names of the parts of a trench is given on Plate 48, Fig. 1. The height from the fire step to the top of the parapet for fire standing is shown as 4 feet 6 inches. This, however, must be modified according to circumstances :—

i. The height of the men varies, and a first condition must be that every man must have a parapet as high as he can fire over conveniently, but no higher. Men must be trained to test the height of the parapet immediately they occupy a trench, and to add to or reduce the height to suit themselves.

ii. The slope of the ground on which the trench is sited will vary. If the trench is sited to fire up hill, the parapet may be slightly higher than that of a trench on level ground ; while if sited to fire down hill, the parapet **must be lower**, if the men are to cover the ground in front with effective fire.

6. When consolidating a captured position, or when providing shelter for troops in a defended position in the first stages of its defence, it will generally

be necessary to entrench small units such as sections or platoons in detached positions. In this case, concealment of the defences from direct observation is all-important and the section of trench to be adopted will have to be of a section such as that shown in Task I, Plate 48, Fig. 2, with the parapet carefully disguised to appear like the neighbouring ground. It will probably be impossible to provide any more elaborate cover without giving up concealment, and it therefore follows that the larger sections of trench will not be suitable until the defences are more or less continuous. This section gives a trench, the bottom of which is the length of a pick helve below the original surface of the ground. **The trench must not be deepened further until it has been widened, as shown in Task II, Plate 48, Fig. 2.** If an attempt is made to deepen the trench before it has been widened, the fire step disappears, so that it is impossible to fire out of the trench, and the trench becomes impassable and collapses under shell fire.

7. Trenches behind the front line, which are generally dug by working parties, should be dug to the full width from the beginning, provided that the tasks can be so arranged (Chapter III) that a depth of 3 feet can be dug in the first relief. No working party should be allowed to leave a trench which may have to be used as a fire trench, until that trench has been dug throughout to such a depth that it gives good cover to men firing standing in it. The advantages of digging a trench to the full width from the start are:—

i. That a proper fire step is assured.

ii. The labour of digging is lessened, because the bulk of the excavation is finished before water can collect in the trench and make the digging difficult.

iii. Trenches dug in this way to the proper slopes last much longer than narrow trenches, which rapidly disappear under the combined effect of weather and shell fire.

8. The completed section of the trench should be of the minimum dimensions shown in Plate 48, Fig. 2. The parapet must be bullet-proof at the top, and the top should be as irregular as possible, provided that it does not interfere with the firer. Slopes should not be steeper than 4/1, and the fire steps should be at least 2 feet wide. The back of the trench should provide a passage at least 2 feet wide at the bottom, which should be a minimum of 6 feet below the top of the parapet.

The interior slope of the parapet should be revetted, if possible, so as to provide a firm support for the forearm of the firer.

A revetted section is shown on Plate 48, Fig. 3. The fire step must be revetted first in all cases, since, when men are firing, the whole of their weight is thrown on to the rear edge of the fire step, and unless the step is wide and the edge revetted, it is very quickly destroyed and the fire bay becomes useless. Bricks, rubble, trench boards or boarding may be laid on the fire step, so as to provide a hard standing at the correct level.

The remainder of the trench should not be revetted if it will stand without revetment (Sec. 60).

When the trench is revetted, the interior slope may in good ground be cut at a slope of 6/1, but not steeper.

The parados should be irregular at the top and 2 to 3 feet high, so as to form a background for the heads of the men in the trench.

9. Parapets must not be under-cut to form shelters, recesses for ammunition, Very lights, &c. ; this practice invariably results in the collapse of the parapet and many casualties from men being buried by shell fire ; if recesses of this nature are required they must be properly lined with steel shelters, corrugated iron, timber, boxes, &c. Fire trenches must be provided with frequent exits, consisting of well-revetted steps, both to the front and rear : exits are required for the use of patrols, to facilitate the reinforcement of trenches in front, and to enable men to get out to effect repairs, engage in new work, and carry out conservancy.

10. Trenches for firing lying down should be made obliquely to the line of fire. The height over which a man can fire in this position is from 9 to 12 inches. The legs of the firer are very exposed to shrapnel, and the trench should be deepened as soon as possible.

11. The adaptation of hedges, walls and embankments as fire positions are described in Sec. 62.

12. The construction of a fire position among shell-holes is described in Sec. 65.

51. *Traverses.*

1. **Traverses** are strong buttresses of earth butting out from the front or the rear face of the trench, so as to split it into a series of compartments. They give protection to the garrison against enfilade fire and localize the effect of a shell or bomb bursting in the trench. For both these purposes they must be strong and solid, and not less than 15 feet thick. The top of the traverse should be higher than the parapet, so as to protect the heads of firers from enfilade and traversing fire of machine guns. The earth forming the top of the traverse should be thrown well forward and occasional forward traverses provided (Plate 46). The traverses, however, should never be higher than the parados, or the fire bays will be marked out by them. Traverses add to the length of trench necessary to accommodate a given number of rifles, but frequent forward traverses minimize this. If traverses are too near together, they make supervision and control difficult. They facilitate bombing attacks along the length of the trench, as grenades can be thrown from under cover of a traverse, generally into the next bay but one. As a protection against this there should be, at intervals in the line, straight lengths of trench in which the distance between two adjacent traverses is beyond the range of a bomb thrown by hand, *i.e.*, 45 yards. The traverses at either end should be loopholed for fire inwards (Plate 49, Fig. 1).

2. Traverses will often have to be made in a completed trench which is insufficiently traversed. To do this cut out a D, the inner trace of which is 15 feet wide, and sufficiently deep to give an overlap of 5 feet. When this D has been dug to depth, drained and trench-boarded, build two revetment walls (Sec. 60) across the old trench and fill in the space so formed with the spoil taken from the D (Plate 49, Fig. 2). Two parties of shovellers will be required, one for filling the space between the revetment walls and the other for reforming the parados.

3. **Bridge traverses** are traverses built across a trench, but which allow traffic to pass below. They are used to screen trenches which are enfiladed by the enemy, and the effect is very much the same as that of the flies in the scenery of a theatre (Plate 50) or screens shown on Plate 20, Fig. 1.

52. *Communication trenches.*

1. To afford protection from enfilade fire and to minimize exposure to shrapnel, communication trenches must be irregular in line, zig-zagged, or traversed. The winding trace (Plate **51**, Fig. 1) is best, but the curves must be sufficiently pronounced to give real protection against enfilade fire. When it can be avoided traverses should not be made in communication trenches, as they make the movement of carrying parties difficult. If traverses are made, they should be rounded to enable loaded men and stretchers to pass; they are easier to revet when rounded than when square. The minimum curve in winding communication trenches so that a stretcher can be carried round it, is 16 feet radius in a trench 3 feet wide.

2. Except in such soil as solid chalk, communication trenches which are required to remain serviceable for a long time or to stand wet weather must be revetted. A berm of 18 inches must be left between the edge of the trench and the parapet. The minimum width at the bottom should be 2 feet 6 inches, but 3 feet is better. Increasing the width reduces the protection afforded, and the width of 3 feet at the bottom should seldom be exceeded. The revetted sides must be sloped at between 4/1 and 3/1. The depth of the trench from top of parapet to bottom of trench or trenchboard should be 7 feet, if possible; the proportion of depth of trench to height of parapet depends on the site and facilities for drainage (Plate **51**, Figs. 2 and 3).

3. **Passing places.**—The communication trenches may be the only means of effecting reliefs in the trench system. Instances have occurred when relieving troops have stuck fast in the trenches and been unable to proceed.

Passing places, and in a long trench occasional sidings, should be arranged; sign-posts should always be placed at the entrance to communication trenches, and at any branches off them, to show where they lead.

4. **Defence of communication trenches.**—Special arrangements must be made to prevent the enemy's bombers working down a communication trench to attack the lines behind. Any communication trench leading into a fire trench from the front must be made straight for the last 45 yards, and Lewis gun or rifle fire provided down the straight portion (Plate **52**, Fig. 1). A dog-leg trench will do, if proper arrangements can be made for enfilading both reaches of it. Provision must be made for blocking this last 45 yards of the trench at both ends. Chevaux de frise ("knife rests") or other wire obstacles are placed in a recess or along berm at the point where the block is to be made, so that the last man to retire can quickly pull them down into position (Plate **52**, Figs. 1 and 2). The straight length must be well wired on both sides.

5. **Communication trenches prepared for use as fire trenches** are of the utmost value for flank defence when the enemy has succeeded in penetrating the front line. T-heads or D-heads should be dug off the trench so as to form fire bays facing in the required direction, or fire trenches should be cut across a re-entrant angle in the trench (Plate **53**): the occupants of these trenches must be protected from rifle and machine gun fire from positions in rear. A communication trench prepared for use as a fire trench should be protected on both sides by a good wire entanglement.

6. **Trench junctions.**—A communication trench should enter and leave a fire or traffic trench as shown in Plate **57**, Fig. 2: communication trenches joining a fire trench should do so at an angle to the expected direction

of fire and not at right angles to the trench; the entrance and exit are separated by a space of at least 30 yards, so that one shell cannot block the communication both ways. The rearward communication trench should come in at an angle to the corner of a traverse, and the forward communication trench should similarly leave from the corner of a fire bay. Well revetted steps must be provided on either side at intervals of 100 to 200 yards to serve as exits.

7. Overland tracks, with all trench crossings properly bridged, on either side of a main communication trench, relieve congestion of traffic at night or by day when conditions are favourable.

53. *Reserve trenches.*

1. **Reserve trenches** should be similar in design to traversed fire trenches. Protection against shell fire in the form of tunnelled dug-outs or concrete shelters (Chapter XIV) should be provided.

2. **Slit trenches** afford very good protection from a bombardment. They are 2 to 3 feet wide and 4 feet deep, dug at right angles to and on either side of the communication trenches. They must be strutted at the top to prevent collapse, and exit steps must be provided at the end away from the communication trench. Each "slit" should be wavy in plan and long enough to hold 10 to 12 men (Plate 54, Figs. 1 and 2). These trenches are used also for cover for reserves, machine-gun detachments, and, in artillery positions, for the personnel of the guns.

54. *Drainage.*

1. **Drainage** of trenches and fire positions is of the greatest importance; if neglected, trenches collapse and disappear in bad weather. Apart from the question of convenience and health, failure to provide it, therefore, may have disastrous results on operations. More trenches are destroyed by neglect of drainage than by the enemy's fire.

The question of drainage must be carefully considered when trenches are sited. Drains should be put at the lowest point of each fold in the ground, and the bottom of the trench graded so as to fall towards them without any intermediate depressions. These graded lengths should be kept as short as possible to limit effects of blocks by shell fire.

Excavation of drains should be done uphill and the bottom of the trench graded before work ceases each day, so that pockets, formed by unfinished tasks, are not left to collect water.

2. **Pumps.**—Every scheme for keeping a trench system clear of water must include an ample supply of pumps: the necessary pumping parties are supplied by the garrison. A simple form of sludge pump is shown on Plate 56.

3. **Sumps** or soakage pits (Plate 55) should not be relied on unless natural drainage is impossible. The only part of a sump which is effective is that below the level of the bottom of the trench; unless the sump reaches a permeable stratum, it must be pumped or baled out. If a sump ceases to absorb water, it is probable that the pores of the permeable stratum have become choked with particles of mud; if the sides of the sump are shaved off it will again absorb water.

Sump pits must be revetted above water level with a skeleton revetment, kept in position by bracing across the sump: below water level, the pits must be revetted with brushwood, X.P.M., or corrugated iron.

When constructing a trench system, until the main sumps can be provided, it will be necessary to provide small sump pits in the trench itself: these must be well revetted, and kept clear by pumping.

4. In ground where the water level is close to the surface, the depth of the trenches must be reduced accordingly and cover obtained by increasing the height of the parapet up to a full breastwork, if necessary. In such soil, sumps are of no value.

5. In occupied trenches, the mud which is churned up by traffic will make drainage impossible, unless trench boards are laid with a clear space for the water to flow beneath them.

Trench boards should be laid as soon after digging as possible, even in dry weather, for, after a heavy shower, traffic will quickly convert the bottom of the trench into a slough.

6. The maintenance of a drainage system is essential and must be carried out by the troops in occupation. Special trench wardens must be detailed for communication trenches, so that blocks caused by falls or shell fire may be removed without delay.

55. *Repairs to trenches.*

The first object in repairing trenches which have become impassable owing to bad weather or lack of drainage is to make them usable and dry. This can only be done by sacrificing depth and cover. The work should be carried out in the following order (Plate 54, Fig. 3):—

i. Cut back berm of old trench to 3 feet (shovel-length).

ii. Cut back the top of the trench, making it not less than 6 feet wide and sloping it to the bottom of the trench irrespective of depth. If the mud at the bottom is bad and is increased in cutting back the sides, leave it in, if it is sticky and difficult to get out.

iii. Put in "A" frames, sinking them into the mud as far as possible, and lay trench boards (Plate 54, Fig. 4).

iv. Clear the mud from between the "A" frames so as to get a good drain right along the trench.

v. Deepen the trench and revet (Plate 54, Fig. 5), being careful to leave at least a 9-inch berm at the tops of the "A" frames.

56. *Sapping.*

1. Sapping consists in constantly advancing a trench in the direction of its length by a party, who work standing on the bottom of the trench and keep themselves under cover by throwing up a parapet on the exposed flank and end of the trench.

The width of a sap is just wide enough to allow one man at the face to use his tools (Plate 58, Fig. 1).

Sapping is the method of making trenches when the fire of the enemy is too accurate to do ordinary trench work, or when it is necessary to establish communications between listening or other forward posts with the front trenches.

The average rate of progress is from 2 to 3 feet an hour. The man at the face must be constantly changed. Saps should be wired in on both sides to prevent the enemy from raiding and capturing the occupants.

2. **Russian saps** (Plate **58**, Fig. 2) are tunnels driven from 2 to 3 feet under the surface in the same way as described for dug-outs and subways in Chapter XIV. They are made to establish concealed communications between the front trenches and the forward posts, or to provide exits from the former for raiding and assaulting troops.

In position warfare, prior to an offensive, Russian saps are driven forward towards the enemy's trenches so as to enable communication to be established as quickly as possible, when these trenches have been captured. A Russian sap is converted into a communication trench by removing the top sills of the frames and allowing the supported earth to fall in. This earth must be cleared away at once, otherwise the sap soon becomes impassable and the sides of the sap must be prevented from collapsing. The side timbers may be kept in place by screwing home short screw pickets in the side of the sap about three-quarters the height of the sap every 5 feet and passing an iron rod or pipe through the eyes (Plate **58**, Fig. 3).

57. *Overhead cover, head cover, loopholes.*

1. **Overhead cover** is never used in any trench which is to be occupied as a fire trench. Overhead cover for shelters and dug-outs is dealt with in Chapter XIV.

Beyond this the only cases in which overhead protection is required are behind defended walls (Sec. **62**, 2), or as a protection against rifle grenades in posts on the lip of a crater.

2. **Head cover.**—Hasty head cover may be provided by placing large stones or bags of shingle in the parapet; the firer must fire obliquely across the parapet in order to get protection from hostile fire. More deliberate head cover is provided by loopholes.

3. **Loopholes.**—All firing by night, and to meet an attack whether by day or night, must be over the top of the parapet. A certain number of loopholes are necessary, however, in all trench systems for the use of snipers to inflict casualties on the enemy whenever opportunity offers, to annoy him, interfere with his work, keep him under cover, and keep down the fire of his snipers (Sec. **58**), and for observation.

Various types of loopholes are shown on Plates **59**, **60** and **61**.

The art of building loopholes so as to make them secure, invisible and convenient for firing at definite points requires most careful study and training. The chief points to be observed are :—

- i. They are usually made at night and, therefore, the alignment must be sited and marked out by day.
- ii. The work must be completed in one night and all signs of new work must be obliterated by daylight.
- iii. The maximum amount of protection must be given to the firer. A service steel loophole plate with a metal flap to close the aperture is the best form of loophole at close quarters.
- iv. The recess must give sufficient room to allow the firer to use his rifle **obliquely** through the loophole from either side (Plate **59**).

v. Loopholes must be concealed from the front and they are therefore set obliquely in the parapet.

vi. Curtains must be hung at the back of the loophole, so that its position is not established by light showing through it.

vii. Concealment may be facilitated if the exterior slope of the parapet is made irregular combined with beams, timber and rubbish of all sorts thrown over it (Plate 61).

The concealment of loopholes by the application of camouflage is dealt with in Appendix X, Sec. 5, 3.

58. *Snipers' posts.*

No definite rules can be laid down as to the best position for snipers. It must be left to the ingenuity and enterprise of the snipers to discover suitable places and to utilise them skilfully. Many excellent places will be found for observation and sniping in rear of the firing line. The best time to reconnoitre for such points is during the evening light, when the enemy cannot see very far, but while it is still possible to see whether they command the view required.

A tunnel through the parapet, if the opening is carefully concealed, may prove a good sniper's post (Plate 61). Sniper posts should be made for two men, one to observe and the other to fire or to make notes.

59. *Observation posts, intelligence posts, look-out posts.*

A good system of observation is of the utmost importance to the artillery and infantry in any form of warfare. Observation and intelligence posts are eyes of the artillery and infantry commanders, respectively, and the enemy will spare no pains to blind them. The utmost care must therefore be taken to conceal these posts, as any building, feature or point which is suspected of being used as an observation post will certainly become a target for his artillery.

For good observation work the observer must be comfortable. A shelf rest in front for his elbows, field glasses, &c., is required.

The post must not be too dark, otherwise the eyes of the observer are strained whenever he turns his head from the bright daylight outside to the darkness within. The rear of the post must not be open to full daylight whenever anyone enters or leaves it, otherwise the enemy can see through the slit and observe such movements as may take place behind it, and the daylight showing through betrays the place as an observation or intelligence post.

The bottom of the slit should be 5 feet 6 inches from floor level, to enable a tall man to use it. A small platform can easily be placed for a short man.

The observation slit should be of irregular shape and not less than 6 inches high. If the slit is less than this, the field of view is too small unless the observer keeps his eye close up to the slit, which attitude is much too fatiguing for prolonged observation. Headroom above the slit should not be less than 6 inches.

The slit should be about 3 inches wide or according to the field of view required.

Observation posts have often become useless from having been built with the slit too near the local ground level; when the grass and weeds grow, observation is obscured, and cutting down is quite impossible in many cases owing to the proximity of the enemy and the amount of clearing required which would naturally betray the observation post.

The floor area must be as small as possible in order to reduce the labour of construction and to facilitate concealment. Thirty-six square feet is the minimum area in which work can be done properly (Plate **62**).

For artillery it should be large enough to accommodate one observer, two telephonists, and maps; the telephonists can be accommodated with advantage below the observer (Plate **63**).

60. *Revetment of trenches.*

1. **Slopes.**—The amount of revetment in trenches can be very much reduced if the sides of the excavations are carefully sloped. There is no difficulty about this provided that the work is properly set out and explained to the men. Unless the slopes are cut smooth and uniform, rain lodges on the uneven surface and soon soaks into the earth and makes it disintegrate and fall.

A trench, A,B,C,D, with well-cut slopes and badly-cut slopes is shown on Plate **64**, Figs. 1 and 2.

Slopes should never be cut at the same time as the excavation is being dug out; the general principle of cutting slopes is shown on Plate **64**, Fig. 3.

Taking the side A B at a slope of 2/1, the horizontal distance from A to B is 3 feet. It will be convenient to dig the full depth of 6 feet in two stages of 3 feet depth.

First stage, leave a step 18 inches wide at A and dig from *a*, vertically down for 3 feet to *b*.

Second stage, leave a step of 18 inches wide at *b* and dig from a^1 vertically down for 3 feet to B.

Third stage, clear the steps by digging out carefully the triangular blocks, A*ab* and ba^1B.

This is done best by first of all digging out narrow slits, W,X,Y,Z, at intervals (Plate **64**, Fig. 3) as guides and then clearing the remainder, using spades or flattened shovels.

The width of the step *a*A is arrived at in this way. The slope A*b* is 2/1, $ab = 3$ feet, therefore $a\text{A} = 18$ inches; similarly for the step $a^1\,b$.

The side CD can be done in exactly the same way, only as the slope of DC is 3/1, the width of the steps would be 1 foot, because the slope of $\text{DC} = 3/1$ and $cd = 3$ feet, therefore $d\text{D} = 1$ foot. In forward work provide party with a templet for width at top and bottom; in more elaborate work use field level.

2. **Selection of type of revetment.**—The principal objections to revetments in a trench are the great amount of time, labour and material required for their construction, and that, should the trench be blown in, the revetting material is difficult to clear away and obstructs traffic; this is particularly the case with corrugated iron, expanded metal and brushwood hurdles. It is often quicker, easier and more satisfactory to dig or clear round than through a trench which has been blown in, especially when the trench has been revetted with wire netting or expanded metal.

The upper part of a trench is most exposed to damage by shell fire and should not be revetted unless absolutely necessary; sandbags and brushwood (but not brushwood hurdles), are most suitable as they can be cleared away with ordinary cutting tools and shovels.

The lower part of a trench is less exposed, and it is convenient to revet it with some more permanent form of material such as corrugated iron, expanded metal, hurdles or brushwood. This provides a firm foundation on which to build the sandbag wall, facilitates drainage, and greatly assists in clearing the trench by providing a hard surface to clear to.

Firesteps should be revetted as soon as the digging is finished. This may be done by using the short "A" frames or pickets with revetting material, such as corrugated iron, expanded metal, brushwood or fascines. Sandbags should never be used for making or revetting firesteps; they become very slippery in wet weather and men cannot get a secure footing to fire from.

Sandbags and gabions are most useful for repair work.

3. Revetments are of two types :—

(*a*) Those which consist of a "skin" held in position against the face of the earth by fixed uprights, *e.g.*, corrugated iron, expanded metal, brushwood or hurdles supported by pickets or frames.

(*b*) Those which are built up like a retaining wall or dam and which hold back the earth by their own weight, *e.g.*, sandbags, sods, or gabions.

4. Type (a).

i. Pickets.—If pickets are used as uprights, their feet must be driven well into sound ground at a slope of 4/1 and their heads securely anchored back so that the pressure of the earth may not force them out of position. The whole efficiency of the revetment depends on this anchorage.

Stout anchorage pickets at least 2 feet 6 inches long should be driven in sufficiently far back from the face of the revetment to be well beyond the angle of repose of the earth (Plate **65**, Figs. 1 and 2), roughly twice the height of the revetment from the face. The revetment pickets should be 2 to 3 feet apart and wired back to the anchorage pickets by at least eight strands of 14 S.W.G. wire twisted together and windlassed tight. These wires should be fastened to the anchorage picket at ground level and to the top of the revetment picket, except in the case of breastworks, when the wire should be attached to the revetment picket at a point about one-quarter of its exposed length from the top (Plate **65**, Fig. 1). The anchorage wires must be perfectly straight.

In bad ground a second anchorage should be driven in 3 or 4 feet behind the first and the head of the latter anchored back to it.

Anchorage should, as a rule, be driven in or laid at right angles to the line of pull.

Screw pickets when used as anchorages should, on the contrary, be screwed in, in prolongation of the line of pull.

A useful type of revetment anchor is shown in Plate **66**.

A hole is made in the ground at the correct angle with an earth auger or picket. Wire is attached to the anchor, and the anchor pushed down the hole, short end first, with a stick.

As soon as a strain is put on to the stay wire, the points of the anchor bite into the sides of the bore hole, and it eventually assumes a position across the hole. (*See* also Sec. **74**, 10).

ii. "A" frames.—(Plates **8** and **9**) provide the supports for trench boards with a drainage channel below.

In using these revetting frames the revetment must commence at the bottom of the frame (Plate **48**, Fig. **3**). The trench must be dug deep enough to allow of this being done. Trenches in which it is intended to use these frames should be checked by means of templets during excavation, 3 inches clearance being allowed on each side of the frames. Earth must be tightly packed below the struts of the "A" frames.

The frames must not be fitted into slots cut in the bottom of the trench.

The frames must be upright and properly aligned so that each takes its share of the earth pressure.

The distance apart of revetment pickets and "A" frames depends on the stiffness of the revetting material used; in ordinary ground they should be from 2 to 3 feet apart, when hurdles or brushwood are used.

iii. **Corrugated iron** is the strongest and most durable revetting material. The sheets should overlap each other by 3 inches, an upright being placed at each overlap and opposite the centre of each sheet.

In waterlogged ground it is advisable to make weep-holes in the sheets to assist in the drainage of the earth behind.

iv. **Expanded metal** should be used in the form of hurdles (Plate **6**) or gabions (Plate **7**). If hurdles are not available, 4 inches by 1 inch longitudinal battens can be nailed to the expanded metal to give it some measure of rigidity; in either case the expanded metal and not the battens should be placed next the earth. When "A" frames are used as uprights, these battens should be nailed or wired to them; this helps to keep the frames in position and strengthens the revetment. For convenience in carrying, the X.P.M. may be rolled up, and the battens nailed on at the site where they will be used. Plate **7**, Fig. **6**, shows a wire hook which is useful for lacing together plain X.P.M. sheets in revetments or gabions.

If expanded metal is used for revetting firesteps, a picket or plank must be fixed along the edge of the firestep to prevent it from being trodden down. Expanded metal hurdles should not be used in positions exposed to heavy shell fire. When hit by gun fire, the damaged hurdles frequently block a trench badly, and are difficult to extricate. Brushwood or light wooden hurdles are better.

v. **Brushwood.**—Remove the leaves and twigs and pack the brushwood in behind uprights spaced at about 2 to 3 feet intervals. The brushwood need not be woven between the uprights. Brushwood is very bulky and requires a great deal of transport; it is most useful for work near woods, where it will be obtained when clearing the field of fire.

If brushwood hurdles are used, they must be held in position by proper uprights; it is not sufficient to anchor back the pickets of the hurdle itself.

vi. **Planking.**—Forest planking or half-round waste outside cuts of logs may be used for revetting in positions not exposed to artillery fire.

vii. **Wire netting and canvas** are almost useless—they bulge excessively under the pressure of the earth.

viii. Hurdles or planks backed by Hessian canvas form a suitable revetment for fine desert sand.

5. **Type (b).**

i. **Sandbags.**—Sandbags should be three-quarters filled with earth or sand so that when beaten with a shovel to a rectangular shape they measure about 20 by 10 by 5 inches. Hard ground, gravel, chalk, bricks, &c., must be broken small so that when the sandbag is filled the material can be shaken into a compact, pliant mass. In this case the sandbags must not be beaten.

A filling party should consist of three men, two holding and tying and one shovelling; building parties should work in pairs. The size of the carrying party connecting the filling and building parties depends on the distance that the bags must be carried. Three men should fill and two men should lay 60 bags an hour, so that the carrying party should be sufficient to deal with this number of bags.

Sandbags rot quickly and should **not be used** when the revetment is required to stand for a long period **if other material is available.** They are used in the repair of damaged parapets and for quiet work close to the enemy.

The revetments must take the form of a properly built and bonded retaining wall, with the thickness at the base proportional to the height; it must not be a mere veneer or skin of bags. The common faults in building sandbags are shown on Plate **67**.

The most important part of a sandbag revetment is the foundation; this must be in sound ground and must be excavated so as to be perpendicular to the slope of the face of the revetment. The "batter" (slope) for a sandbag revetment is 4 in 1; the foundation must, therefore, be cut to a slope of 1 in 4.

In unsound ground the foundation of the sandbag must be revetted; short "A" frames are best for this purpose.

A bag is said to be a "stretcher" when it is laid with its longest side parallel to the face of the wall, and a "header" when at right angles to the face. The bond used in sandbagging is known as English Bond, *i.e.*, alternate course of headers and stretchers (Plate **67**). The first course should be headers. Headers should be laid with the chokes (tied ends) towards the parapet; if a stretcher has only one seam, this also should be turned towards the parapet.

ii. **Sods.**—Sods should be laid in the same way as sandbags, grass downwards; if available a split picket should be driven through each sod to hold it in position and strengthen the revetment. Bundles of heather and grass can be used in the same way for temporary work.

iii. **Gabions.**—Gabions should be set at a batter of 4 in 1, on a foundation as described in sub-para. i. above. They should be filled solid and kept steady by earth thrown up against them at the same time.

If sandbags are used above the gabions, they must be set back behind their edge to prevent the expanded metal from cutting the bottom layer of sandbags.

61. *Breastworks.*

1. **Breastworks** are made when it is impossible to obtain cover by digging trenches; for instance, in rocky country where there is little or no earth, and in marshy country where the water lies on or close to the surface. Their construction is slow and laborious. In spite of their being more conspicuous than trenches, well-built earth breastworks are not damaged unduly by artillery fire and are more easily repaired than trenches.

The trace and profile of breastworks follow the same general rules as for trenches. The parapet must be at least 5 feet thick at the top, the exterior slope between 1/2 and 1/3, and the borrow-pit, from which the earth for the parapet is obtained, must be traced so that a berm of 3 feet is left between the toe of the exterior slope and the edge of the pit (Plate 57, Fig. 1).

2. Breastworks must be constructed with traverses in the same manner as fire trenches, and must have a firestep, to allow of every man using his rifle over the top. The necessary amount of cover for free movement along the line (6 feet 6 inches as a minimum) can be obtained, either by building up the parapet to this height, when a raised firing step will be required, or by having the firing step at ground level and digging a narrow shallow trench immediately behind it and round the ends of traverses. A parados must be constructed to protect the garrison from the backblast of high explosive shells. This parados should be bullet-proof (4 feet thick) at its top, and strongly revetted on both faces. It should be as high or slightly higher than the parapet. A path paved with brick or trench boarded just behind the parados is a great convenience; it should communicate with the fire bays by openings through the parados behind at least every other traverse. The space between the breastwork and parados should be trench boarded, and drainage must be provided.

3. The labour of moving the earth, required to make a breastwork, by shovelling only, is so great that some special arrangements must be made to reduce it. Wheelbarrows, hand barrows, baskets, wheeling planks, trench boards for tracks, and horse scoops should be employed as required.

4. A breastwork once begun should be completed as quickly as possible, for, while incomplete, it is very vulnerable to artillery fire. It is also important to complete the work in dry weather, for the borrow-pits are likely to fill with water and progress is then very slow if not impossible.

5. A breastwork may be constructed as follows:—

Put up two revetments of gabions or hurdles—or if using sandbags build two sandbag walls—10 feet apart; fill in between with earth; build up a bursting course in front; finally make a very gentle slope to the front.

6. Breastworks constructed of sandbags are much more vulnerable to artillery fire than earth breastworks. Sandbags are used when silent work is required. A sandbag breastwork must be built in the same manner and with the same precautions as laid down for the sandbag revetments (Sec. **60**, 5).

7. If shelters for men are required, these must on no account be constructed under the parapet, but behind the parados. Each shelter so constructed will require a parados of its own.

8. **Sangars** used to denote the rough dry stone walls behind which Indian Frontier tribesmen fight. The term has now come to include breastworks built of stone. All dimensions given for breastworks apply equally in the case of sangars, but the exterior slope, if not liable to shell fire, may be made steeper. The top 5 or 6 inches of the parapet should be of sods or earth if available in order to minimize casualties from splinters, and it is preferable

that the earth should be in sandbags so that it shall not be blown away in a wind.

Large stones of irregular sizes, varying from the size of a man's head to 18 inches or more in diameter, should be placed on top of the parapet.

The elbow rest should, where possible, consist of earth-filled sandbags for greater comfort. If the sangars are liable to shell fire and any earth is available, the parapet may be constructed as shown in Plate 206. If they are not liable to shell fire, the top of the wall should be at least 2 feet 6 inches thick to avoid any chance of bullets finding their way through interstices between stones. The exterior slope may in this case be 4/1. If the sangar is liable to reverse fire, a parados will be required. Further remarks on the building of sangars in mountain warfare in India will be found in Appendix XI.

9. **Stockades** are walls prepared for defence or breastworks built of timber. Their thickness will vary according to the armament of the enemy (*e.g.*, in West Africa and on the North-East Frontier of India provision need not be made at present against modern fire arms). Their loopholes must be arranged so as to bring flanking fire on each face and at such a height that the enemy cannot use them from the outside, *i.e.*, 6 feet 6 inches from ground level.

62. *Defence of hedges, walls, &c.*

1. **Hedges.**—It is most important to conceal the fact that the hedge is occupied; for this reason, the back of the hedge must be cleared so that the upper branches may form a screen against aeroplanes, and the front of the hedge must be cleared so that the defender can see and fire through without being seen, and so that the foliage or branches hide the earth which has been excavated and thrown to the front to make the parapet. The front of the trench must be close to the centre of the hedge, so that its thick stems may interfere with the firer as little as possible (Plate 68).

If the ditch is on the enemy's side of the hedge, excavated earth can be thrown into it and then covered with the trimmings of the hedge.

Hedges should be trimmed in front with a jack knife and not in a wholesale manner with billhooks or hand-axes.

The roots of hedges will make the work of excavation difficult.

2. **Walls.**—It is rarely advisable to occupy walls if the enemy's artillery is efficient—machine-gun fire would usually enforce the use of loop-holes. In any case, men occupying walls or buildings should be protected from falling debris by overhead cover (Plate 68, Fig. 5).

3. **Embankments and cutting.**—Fire positions in these features are easily made by cutting "D" and "T" heads into the bank; the chief point to be remembered is that protection from the back burst of shells must be provided as shown on Plate 69.

D-heads should be 30 feet long, so that both entrances cannot be destroyed by one shell.

63. *Blockhouses.*

1. **Blockhouses** are small isolated buildings prepared for defence, which are only suitable for occupation if the enemy has no artillery. Their chief use lies in the economical protection of communications generally and important points in particular such as bridges, tunnels, defiles, pumping

stations, halting places, depots, convoy meeting places, railway stations, camps, &c. Permanent masonry blockhouses with machicoulis galleries are in extensive use in India on the frontier and elsewhere for some of the above-named purposes.

2. Semi-permanent blockhouses are usually made of a combination of wood or corrugated iron and shingle in which a dwarf rubble wall or bank of earth supports two corrugated iron skins 6 inches apart, packed with hard shingle; loopholes being provided as necessary. The roof is composed of corrugated iron or a tent, the whole structure being supported on a wooden frame. The entrance is partially underground and protected by a traverse.

A circular fire trench should be provided for the sentry, and a wire entanglement constructed round the completed blockhouse; provision must be made for the storage of water.

3. Blockhouses can equally well be built of dry stone walling. If liable to be fired into from hills near by, the roof should be made bullet proof; if protection from weather only is required the roof may consist of a tarpaulin or any other material available. The shape of a blockhouse is immaterial so long as it allows fire to bear in the requisite directions.

64. *Defence of buildings.*

1. **Buildings exposed to artillery fire** are readily penetrated by shells of light calibre and may be destroyed by a comparatively short bombardment. It will, therefore, seldom be worth while expending time and material on elaborate defensive measures on such buildings; it will usually be preferable to hold outlying hedges, walls, &c., and to strengthen the cellars for use as dug-outs (*see* Sec. **24**).

2. **Buildings not exposed to artillery fire** may be of great defensive value. The considerations stated in Sec. **1**, 4, are applicable. Preparation for defence will include the following:—

- i. Clearing the field of fire; this may include demolition of walls, outlying buildings, &c., but the debris must not afford cover.
- ii. Completion of the defensible enclosure by barricading of doors and ground floor windows. Doors wanted for use require special treatment.
- iii. Construction of fire positions. Loopholing of doors, windows and walls. Provision of flanking fire, and bombing posts.
- iv. Construction of obstacles and strengthening of existing obstacles. Illumination to be provided at night where possible.
- v. Improvement of communications within the building.
- vi. Arrangements for storing ammunition, provisions and water.
- vii. Medical and sanitary arrangements.
- viii. Fire fighting appliances.
- ix. Visual signalling arrangements.

In addition, if the building is large and strongly built and if it be required to make a protracted defence, a small portion should be specially fortified as a "keep" to be held as a last resource.

3. **Details of defence** :—

i. *Doors*.—Doors not required for use should be securely barred and bolted and may be strengthened by :—

(*a*) Strutting from the floor on the inside.

(*b*) The provision of stout battens or steel rails secured across the frame.

To render bullet proof, steel plates may be fixed or floor boards or corrugated iron nailed across the inside of the frame and the space filled in with shingle not less than 6 inches thick.

Loopholes may be constructed as required (Plate 72).

Doors required for use should be protected against surprise assault and may be treated as in Plate 72, Fig. 2.

ii. *Windows* may be protected by :—

(*a*) Loopholed steel shields fixed to the frames.

(*b*) Shingle between boards or corrugated iron.

(*c*) Sandbags filled with shingle.

Loopholes as required.

If the material used for the protection of upstair windows brings an excessive weight on the floor, it may be necessary to strengthen this by strutting from underneath.

If the window is required for bombing, a space should be left at the top and should be covered with a bomb screen made of light timber and X.P.M. (Plate 72, Fig. 3). Otherwise, the protection should be carried the full height.

iii. *Loopholes* are more easily constructed in windows and doors than in existing walls ; the latter may seriously weaken the building. They must be carefully sited and constructed to give the necessary elevation and traverse of fire and at such a height that they cannot be used from outside. The narrow end should be on the outside. They should be concealed as far as possible and blocked when not in use. Loopholes required for bombing should slope slightly outwards and the aperture should be sufficiently large for a bomb to pass through with certainty.

iv. *Flanking fire* can be arranged by building out stockades in front of doors or windows. A roof of corrugated iron or X.P.M. should be provided, sufficiently sloped to throw off bombs (Plate 72, Fig. 5).

A similar structure can be built out of an upper window, supported on beams securely anchored to the floor.

v. *Obstacles*.—In addition to the obstacles described in Chapter VII, it may be advisable to construct an entanglement close up to the foot of the exterior walls, to prevent the placing of explosive charges and to give additional protection against a sudden assault on such vulnerable points as windows, doors, &c. (Plate 72, Fig. 5).

65. *Shell-hole and crater defences.*

1. In heavily shelled ground the shell-holes can be quickly converted into a hasty defensive position. These positions should be organized in depth to afford material support by flanking fire.

It is almost impossible to conceal organized shell-holes from low flying aeroplanes, and they are easily detected in air photographs unless covered by a circular screen as shown in Plate **187** and described in Sec. **5**, 5, Appendix X.

Organized shell-holes can be concealed from ground observers if the following instructions are observed :—

No fresh earth is to be thrown up.
The lip of a shell-hole is not to be disturbed.
Excavated earth is to be dumped in neighbouring shell-holes if not required for cover.
Routes to occupied shell-holes are to be changed constantly.
Connecting trenches must be narrow and camouflaged.

Drainage of shell-holes, though a difficult problem, is of vital importance. Small shell-holes may be connected by drains to deeper holes or it may only be possible to dig a sump in the bottom of each hole covering it with a trench board (Plate **73**, Figs. 1 and 2).

In sodden ground fresh shell-holes are drier and easier to work in than old ones, but in drier soils the sides of old shell-holes are more settled and are free from gas.

Where the shell-holes are not waterlogged large deep ones can be selected and rapidly organized for defence. Fire positions should be made first, either by cutting away the front face or, if the soil is much disintegrated, by digging slits outwards. Labour is saved if the cutting line be taken about half-way down the slope of the shell-hole; a deeper cut can be made in a shorter time than if the forward edge of the shell-hole be taken as the cutting line. If the firestep is to stand unrevetted it must be dug in the more solid earth beyond the radius of rupture; but revetting is necessary in any ground which has been subjected to heavy shelling. In all work it is most important to avoid undercutting, unless the soil is properly supported.

Later, when further work is possible, the position can be made stronger either by digging out a **T**-head in front or by widening the first firing position into a small crescent-shaped trench (Plate **73**, Figs. 3 and 4).

Where the shell-holes are contiguous they should be selected in pairs to accommodate a section, and the rear faces of the pair joined up, thus making the ground between them into a traverse (Plate **74**, Fig. 1). Plate **74**, Fig. 2, shows a shell-hole position. Details of a Lewis gun emplacement are shown on Plate **75**.

Owing to difficulties of command and communication, the organization of shell-hole defences can be considered a temporary expedient only, during the construction of a trench system in ground which has been as little damaged by shell fire as can be found on a suitable alignment.

2. Defence of craters.—When two opposing forces settle down into position warfare it is possible that one or other of them will commence to mine. If craters are formed it is important to occupy them at once, because of the increased observation which is usually obtained from posts on the lip of the crater.

The occupation of these posts should be planned in consultation with the officer in charge of the mining of the sector.

Two schemes are shown on Plates **76** and **77**, which indicate the nature of the work required. Each post must be carefully protected with wire

(Plate 77); shelters must be provided for the men of the post giving protection against rifle and hand grenades.

The inside of the crater must be watched as well as the outside of the lip; this is done by observation tunnels (Plate 76). The posts on the crater must be connected with the trench system by communication trenches.

The construction of a crater position absorbs a large amount of labour, especially in carrying parties, owing to the heavy material required to ensure that the revetments shall effectively withstand the strains brought about by the settling of the debris. It is usually impossible to obtain good holding ground for anchorages, and frames consisting of two uprights and a ground sill, or special deep "A" frames (Plate 9) must be used; pit props, 6 inches in diameter, are the most suitable material.

66. *Defence against gas.*

Defence against gas will be confined to rendering shelters, dug-outs and cellars gas-proof by means of specially designed curtains and air filters.

The entrances to all dug-outs, shelters and mine shafts within the alert and ready zones should, if possible, be provided with gas-tight doors or with curtains of anti-gas material, fitted so as to give a good joint at the sides and bottom of the doorway, thus stopping all draughts. If two curtains are used with a space between them complete protection is obtained, and it is possible to enter or leave the dug-out without introducing appreciable quantities of gas.

A frame of 4-inch by 1-inch timber, covered with anti-gas material, is fixed flush with the wall, sloping outwards at an angle of 20° from the vertical. Anti-gas material is cut to the required size, so that when fastened to the top of the frame it will close the entrance completely with about 9 inches resting on the ground. Three pairs of laths are nailed horizontally to the curtain to keep it stretched. The lath on the underside must be 1 foot shorter than the one on the front, so as to clear the frame (Plate 158, Fig. 1). The lowest of the laths should be 4 inches from the floor. Two curtains should be provided, as shown in the diagrams. The frame for the inner curtain should slope inwards, as shown on Plate 155. All wires and pipes must pass through the frame, which may be widened on one side to allow of this, and the hole through which they pass must be made gas-tight. They must not interfere in any way with the adjustment of the curtain (Plate 158, Fig. 2). The curtains should be not less than 3 feet apart, so as to allow a man to stand between them and adjust one before raising the other. The distance must be increased for dressing stations to allow stretcher cases to be carried in.

Frames for gas curtains should be built into the entrances of pill-boxes and other shelters while the entrances are in course of construction. Machine gun loopholes in pill-boxes should be lined with wood on the inside edges, so that they may be closed with frames covered with anti-gas material. Openings in the sides or roofs of shelters and cellars must be provided with curtains or closed with sandbags, so that no gas can enter. Care must be taken to provide means for closing ventilating shafts and flues.

When not in use curtains must be kept rolled. (Plate 157, Fig. 1.)

67. *Cover for anti-aircraft guns and searchlights.*

Experience has shown that anti-aircraft defences are liable to repeated attacks by aircraft and they must, therefore, be provided with suitable protection.

For the personnel, shelters or dug-outs, as described in Chapter XIV, will be constructed. The lorries will be protected best by being run into a cutting in the bank of a sunken road.

Plate **78** shows a type of emplacement for a 90 c.m. or 120 c.m. anti-aircraft searchlight, suitable for skew gear pipe control with telescope.

68. *Field defences for artillery.*

In the following paragraphs are described only those measures for protection which apply exclusively to the artillery.

1. **Temporary battery positions.**—The construction of battery positions which are likely to be occupied for a short time only should aim at protection for the gun detachments from shell splinters while in action and cover against bombardment (*see* Sec. **53**, 2). With this object in view, slit trenches should be constructed at once for the command post and gun detachments, and the earth thrown out from the latter utilized to form parapets round the guns.

2. **Battery positions in position warfare.**—Before any work is begun the site must be camouflaged on a sufficient scale to conceal every indication of work. The position will be located if work is started before the camouflage is complete, and time, labour and material spent on camouflage subsequently will be wasted. The methods to be employed are given in Sec. **7**, Appendix X. The cover should be progressive, depending on the time, labour and material available, from weather-proof, splinter-proof, to shell-proof.

3. The command post and dug-out for the wireless operator must always take precedence of cover for the gun personnel and ammunition.

A command post, including the telephone, can be accommodated in a space 9 feet by 9 feet by 6 feet 6 inches high (Plate **79**), but a separate chamber for the telephone is a great advantage.

A convenient position as regards the battery is from 20 to 60 yards in rear and to one flank of it. It should be provided with an entrance on the sheltered side and a prepared stand from which to megaphone to the guns.

When the battery is split up into sections, each section commander will require a similar post.

The wireless chamber, when provided, should be sited clear of the battery position, with separate inter-communication to it.

4. **Shelters for personnel.**—The following instructions apply specially to shelters for artillery personnel.

Neither officers nor men are to be accommodated *en bloc* in any dug-out which is not shell-proof.

Dug-outs for cooks, men off duty and spare telephonists may be made well clear of the battery.

Dug-outs near the gun must not lead direct into a closed gun pit, owing to the risk of gas poisoning from the carbon monoxide produced during firing.

The dug-outs near gun pits must be protected as described in Chapter XIV.

5. **Shelters for ammunition.**—There are no fixed sizes for ammunition shelters, and any available shelter can be used, provided that not more than

50 large and 100 small shells are stored together in one shelter, and that large quantities are divided up by traverses not less than 4 feet thick. The important point is that the cartridges, other than those of fixed ammunition, should be separate from the shell.

Recesses for 18-pr. ammunition may be made in the gun pit. These can be made with wooden uprights and shelves made of angle iron pickets. In the gun pit, not more than three shelves should be placed in each recess, and not more than two layers of ammunition on each shelf. The shells must be kept from contact with the ground. The recesses must, therefore, be floorgd with planks, trench boards, brushwood, &c., and lined with canvas or boardine.

A type of shelter for dry ground is shown on Plate **80**. It should not be constructed in the communication trench between guns.

Ammunition for field guns can also be stored in a trench as described below for ammunition for medium and heavy artillery. Ammunition is not to be stored on the berm of a trench; this will make the sides collapse.

Recesses for 60-pr., 6-inch, 8-inch and 9·2-inch howitzer cartridges may be made:—

i. In banks.
ii. In trenches specially dug for them.

They must not be stored in the emplacements. Recesses in banks should be made at 6 feet interval and only sufficiently deep to allow one row of cartridge cylinders lying on their sides, or one row of metal-lined cases—the height depends on the number of charges to be stored, which may be as follows:—

In cylinders, 30 to 40 for each recess.

In metal-lined cases—not more than 60 charges for each recess; according to the calibre of the gun or howitzer.

Cartridges should be kept about 12 inches above the ground. If wood is used for this purpose, it should be covered with tin or corrugated iron as a precaution against fire. Cartridges must be screened from the sun's rays.

If no bank is near the battery, the cartridge recesses must be made in a similar manner along the sides of a trench. The trench must be deep enough to allow a man to walk upright in it. Entrances must be provided at each end to ensure a through draught, and they must be stepped.

The trench and recesses must be covered with a weather-proof roof, and the trench must be drained.

When cartridges are kept in metal-lined cases these should be laid on their sides to prevent entry of damp and rain when the luting is removed from the lid, and to facilitate the extraction of the cartridges.

A splinter-proof ammunition recess is shown on Plate **81**. Shell-proof protection for ammunition, if required, will be provided on the same lines as that for personnel described in Chapter XIV.

6. **Gun emplacements** may be classed as:—

i. Camouflaged emplacements without any protection.
ii. Camouflaged emplacements with splinter-proof protection.
iii. Camouflaged emplacements with shell-proof protection.

The last case requires special material and skilled labour, and is dealt with in Military Engineering, Vol. II.

The extent to which it is possible to sink a gun below ground level depends on the nature of the ground and the minimum range at which the gun has to fire. All emplacements must be made so that the gun can be run in and out without difficulty. Drainage must be provided for (Sec. 54).

Diagrams showing the minimum vertical and horizontal dimensions of emplacements of various types of guns, &c., are shown on Plate 82. These may be modified according to the traverse required.

Embrasures and entrances of emplacements can be protected by the methods shown on Plate 83. The protection can be adjusted according to the switch required. A wooden framework hung of 9-inch by 3-inch timber, with six layers of wire netting nailed on in front and four layers behind, will also prevent splinters entering the embrasure.

The embrasures and entrances of covered gun pits and splinter-proof screens must be covered with light removable screens to hide the shadows which are invariably cast (*see* Appendix X).

Splinter-proof overhead cover, and, if necessary, shell-proof cover, can be provided for the lighter natures of guns and howitzers. For the larger pieces overhead covers can be provided by using heavy steel joists or girders, or the latter may even be built up in timber. The work, however, entails considerable expenditure of time and material and with these larger pieces it is usually sufficient to provide splinter-proof protection on all sides. This should be done in the case of all emplacements whenever possible.

7. **Reverberation.**—Gun pits constructed of corrugated steel shelters, or any gun pit, the roof and walls of which are curved, are much more noisy than rectangular pits.

The gun, being along the centre line of the curvature, is the centre to which the sound returns after striking the sides. The reverberation which is set up is distressing to the gun detachments and especially to the gun layers.

Reverberation can be reduced by making the forward portion of the pit curved and the rear rectangular.

8. **Platforms.**—A platform for any nature of gun or howitzer consists of two parts—a support for the trail and a bed for the wheels. The former is the more important and work should always be done on this first. Both are essential if prolonged firing is to be carried out from the same position and, for equipments which do not carry their own platforms, must be improvised from the material available.

9. **Trail support.**—(*See* Plate 84.) This should consist of two parts:—

i. A fixed support, which may be of concrete or pit props firmly fixed with pickets. It should be circular in shape so that the thrust is always at right angles to the tangent to the curve at the point of support.

ii. A cushion, which may be formed of sandbags, blankets, or sacks stuffed with hay or straw.

10. **Wheel-bed.**—This may be made of any of the following materials:—

Natural earth.
Rubble or brick well rammed.
Wood.
Concrete.

i. **Natural earth,** under the best conditions, will only stand a limited number of rounds, dependent on the nature and weight of the gun.

ii. **Rubble or brick,** well rammed, forms an excellent wheel-bed (Plates 85 and 86). It should be at least 1 foot deep, and may be extended across the pit, or may be packed in wooden boxes to form a bed for each wheel, if there is a difficulty in obtaining material.

iii. **Wooden** wheel-beds facilitate the man-handling of the gun, are portable and can be put together quickly.

They should be made of sleepers or 9-inch by 3-inch planks, dogged together not nailed (Plate 87).

Wheel guides may be added to keep the gun in its line of fire and prevent "frogging" (Plate 87.)

A simple form of wheel guide consists of the tyre of a gun or G.S. wagon wheel, spiked to the platform.

iv. **Concrete** forms a good wheel-bed if time is available to allow it to set; it is useless unless well mixed. The concrete may be extended across the pit or a separate bed for each wheel may be made.

Wicker or fascines are unsuitable as they cause erratic shooting and are not desirable. "Mats, gun, wheel" answer the same purpose.

11. **Details of platforms for the various natures :—**

i. **Light artillery.**—The cushion for the trail support may be fixed with wire in the angle between the spade and trail-eye.

With the 18-pr. Mk. II equipment, if the length of time it is expected to occupy the position justifies it, better results will be obtained if two or three trail supports at varying heights are prepared for use at different angles of elevation (Plate 85).

ii. **Medium artillery :—**

(*a*) **60-pr.**—Pit-props make a suitable trail support. As a temporary measure, fascines laid under the trail in front of and behind the spade are of great assistance in preventing the trail from burying itself.

If whole bricks are obtainable, they may be placed on edge on a layer of expanded metal with brick rubble on top. It is advisable to enclose the whole in a wooden box held in place by pickets.

(*b*) **6-inch howitzer.**—Brick rubble is the best trail support with a fascine placed in the spade as a cushion, as the trail is liable to buckle if the support is too firm. The rubble requires constantly replenishing. In soft ground it may be necessary to place a baulk in the spade to prevent the trail burying itself.

In wet ground a bed constructed of one layer of 9-inch by 3-inch timber is necessary (Plate 88).

iii. **Heavy artillery :—**

(*a*) **8-in. howitzer.**—Mark VI and upwards carry their own platform, but for the earlier marks of carriage a double-decked platform of wood is necessary.

(*b*) **9·2-inch howitzer.**—This howitzer carries its own platform in the form of firing beams, but in many cases this must be supplemented by a bed of hard material.

69. *Screening.*

1. The primary aim of screening is concealment from view in order to permit free and unobserved circulation of traffic.

Screening may be carried out by means of :—

i. Artificial screens.
ii. Natural screens.

2. Artificial screens are made of :—

i. **Wire netting** woven with grass, brushwood, or canvas strips (Plate 89, Fig. 1).
ii. Brushwood and tree branches interwoven on horizontal wires stretched tightly between two uprights.
iii. Canvas, or coir, suspended on strongly braced poles.

Of these, canvas and coir do not stand the weather well and require more maintenance on this account.

3. **Natural screens** are made by supplementing the height or thickness of existing hedges, copses or fringe of trees to render them more effective without making the fact that they are screens conspicuous.

A screen should be sufficiently opaque to hide movement from any but very close and continuous scrutiny. The efficiency of any screen, except one absolutely opaque, is influenced by the background. A comparatively transparent screen may be successfully used in combination with a background of hedges and trees, or if it is set obliquely to the enemy's angle of view.

In order to hide movement at ranges between 2,000 and 4,000 yards three-quarters of the surface of the screen should be opaque. Screens may be either plain or camouflaged.

4. **Plain screens** are those which are put up without any idea of disguising the fact that they are screens. Newly erected screens always draw fire, but if the damage is regularly repaired, the attention paid to them rapidly diminishes.

These screens have been used with effect as follows :—

i. The act of screening an area or battery position before they were required drew fire from the enemy for a period during which the screens were regularly repaired.

When the screens were no longer shelled, they fulfilled the functions for which they were erected without further interference.
ii. To conceal a party working behind them.
iii. To draw fire while work was being carried out at a distance to the flank.

Although plain screening affords protection from view after the enemy has ceased to notice it, a careful reconnaissance of the area to be screened should always be made in order that full advantage may be taken of the natural features.

5. **Camouflaged screens** are made of canvas or wire netting combined with canvas, brushwood, grass, &c., painted to reproduce a definite locality such as a brick wall ruin, hedge, &c., or a general landscape. These

should only be used in places where required for a short time because the paint does not stand the weather long and they require constant watching and careful maintenance.

These screens have been used with effect as follows :—

i. Imitation brick walls painted on canvas backed with wire netting to screen a much-used thoroughfare (Plate 89, Figs. 3 and 4).

ii. Imitation hedges of a combination of raffia, canvas strips, and brushwood, on wire netting were made to conceal a battery position which would otherwise have been under direct observation. In this case an existing hedge which was too far back to be used was removed and the imitation hedge substituted for it in front of the guns.

6. If an area occupied during the summer is likely to be occupied during the winter months as well, the problem of screening should be considered early so that the loss of cover due to the leaves falling from the trees may be made good with brushwood beforehand, and no change be noticeable in the landscape when the trees and hedges are bare.

7. **Road screens.**—Roads running perpendicular to the front line are best screened by hanging vertical screens between trees or houses, or poles, across the road (Plate 90, Fig. 1).

For roads running parallel to the front, short lengths of about 30 yards, placed in echelon and overlapping each other, are better than long continuous lengths. This method permits of plenty of passage ways, and limits damage by shell fire (Plate 90, Fig. 2).

Roads running obliquely to the front can be concealed by screens facing the front, arranged in echelon (Plate 90, Fig. 3).

8. **Flash screens.**—Screens have been used successfully to hide gun flashes at night from the front and from a flank.

In one case where the flashes of a battery were visible from a flank, six small screens were erected, one about 4 yards to the right of the muzzle of each gun, and running out about 8 yards to the front. They were about 8 feet high. They were dismantled during the day and re-erected each night, in socketed holes.

70. *Manufacture, erection and maintenance of screens.*

1. **Manufacture.**—Screens should be made up in bays of 30 feet, with supports 10 feet apart.

In order to localize the effect of shell fire, each longitudinal width of wire netting should be suspended independently on a longitudinal wire between the uprights.

The screens are made of strips of canvas interlaced in wire netting. The strips should be $2\frac{1}{2}$ inches wide, and threaded through every third or fourth mesh vertically, leaving no horizontal interval. Opacity can be considerably increased by the use of alternate vertical bands of plain and dark-coloured canvas, each band being about a foot wide. There should be a strong contrast between the plain and coloured canvas. Such a screen is effective at ranges of a mile and upwards (Plate 89, Fig. 1).

Still better results can be obtained if the colour is arranged on the vertical bands so as to produce a chequered effect.

Irregularity of outline, if necessary, can be given by not commencing the threading of every strip at the top of the wire netting, or by inserting a brushwood crown.

The material for artificial screens should be as light as possible and allow of simplicity in erection, whilst it should offer the minimum resistance to the air compatible with its efficiency for screening purposes.

2. **Erection.**—Whenever possible, screens should be attached to existing objects such as trees, hedges, houses, &c. If poles have to be used instead they should be sunk well into the ground and well guyed. The screen is fastened with staples to the poles. The uprights are joined by longitudinal wires 3 feet apart, and cross diagonal bracing between each pair, which should be guyed in the normal way (Plate 89, Fig. 1). These wires also form horizontal braces to the uprights which are cross braced and guyed as shown on Plate 89, Figs. 1 and 2. Uprights should be of at least 3-inch timber. Guys should consist of at least four strands of No. 14 gauge wire, or the equivalent.

Screens should not be erected piecemeal, or unnecessary casualties from shelling will be incurred. The material should be laid out on the ground beforehand, so that the whole screen can be erected in one night.

PART II.—BRIDGING

CHAPTER X

KNOTTING AND LASHINGS

71. *Knots.*

The following are the most useful knots and their principal uses :—

Thumb knot and Figure of 8 knot (Plate **91**, Figs. 1 and 2).—To make a stop on a rope, or to prevent the end from fraying, or to prevent its slipping through a block.

Reef knot (Plate **91**, Fig. 3).—To *bend* or join two dry ropes the same size.

Single-sheet bend (Plate **91**, Fig. 4).—To join two dry ropes of different sizes.

Double-sheet bend (Plate **91**, Fig. 5).—To join two ropes with great security, or for wet ropes of different sizes.

Hawser bend (Plate **91**, Fig. 6).—To join large cables.

Bowline and running bowline (Plate **91**, Figs. 7 and 8).—To form a loop or **bight** on a rope which will not slip. The loop formed by passing a bight through a bowline loop at the end of a rope is called a **running bowline**.

Bowline on a bight.—To form a double loop in the middle of a rope—made with the rope doubled (Plate **92**, Fig. 7).

To secure the ends of ropes to spars, pickets, &c., or to other ropes, the following hitches are used :—

Clove hitch (two half-hitches) (Plate **92**, Figs. 1 and 2).—Generally used for the commencement and finish of lashings.

Timber hitch (Plate **91**, Fig. 9).—For holding timber, &c., where the weight will keep the hitch taut.

Two half-hitches (Plate **92**, Fig. 3).—For making fast the running end of a rope on to its standing part.

Round turn and two half-hitches (Plate **92**, Fig. 4).—For **belaying** (or making fast) a rope so that the strain on the rope shall not jam the hitches. This will be used for making fast a rope to a bollard or anchorage. Should the running end be inconveniently long, a bight of it should be used to form the half-hitches.

Fisherman's bend (Plate **92**, Fig. 5).—For making fast when there is a give-and-take motion, *e.g.*, for bending a cable to an anchor.

Lever hitch (Plate **92**, Fig. 8).—For drawing pickets by a lever and fulcrum fixing the rounds of a rope ladder, fixing bars to drag-ropes, &c.

Man harness hitch (Plate **92**, Fig. 9).—To form a loop on a drag-rope which will not draw tight; the loop being of a size to pass over a man's shoulder.

Running knot (Plate **92**, Fig. 6).—To form a loop which will draw taut round an object.

Catspaw (Plate **93**, Fig. 1), or,

Single Blackwall hitch (Plate **93**, Fig. 2), or,

Double Blackwall hitch (Plate **93**, Fig. 3).—To secure a rope to a hook.

Draw hitch (Plate **93**, Fig. 4).—To secure boat's painter, &c., to a post, ring, or rope, so that it can be instantly released. This knot will stand a give-and-take motion, and can be instantly released by a jerk on the running end.

Stopper hitch (Plate **93**, Fig. 5).—To transfer the strain of one rope to another for use on occasions when it is necessary to shift the strain off a rope temporarily.

Magnus hitch (Plate **94**, Figs. 1 and 2).—To make fast to round spars when much friction is necessary to prevent slipping.

Rolling hitch (Plate **94**, Fig. 3).—To make fast a rope end round an object, or secure a rope to a hook.

72. *Lashings.*

1. A **rack lashing** consists of a 6-foot length of 2-inch rope, with a pointed stick about 15 inches long at one end. It is used for fastening down ribands at the edge of the roadway of bridges.

2. **Square lashing.**—To lash one spar square across another, commence by a clove hitch on spar (*a*) below (*b*) (Plate **94**, Fig. 4), and twist the ends together, carry at least four turns round the spars, as shown in figure, keeping outside previous turns on one spar and inside on the other; two or more **frapping** or cross turns are then taken, the corners of the lashings being well "beaten in" during the process; finish off with two half-hitches round the most convenient spar.

When the spars are the leg and transom of a trestle or frame, the clove hitches should be on the leg below the transom, and the lashings should be finished off on the transom outside the leg. When the spars are leg and ledger, the clove hitch should be on the leg above the ledger.

3. **Diagonal lashing.**—To lash two spars together that tend to spring apart. Begin with a timber hitch or running bowline round both spars and draw them together, then take three or four turns across each fork and finish with frapping turns and two half-hitches (Plate **94**, Fig. 5). When the spars are not horizontal, the lashing should be finished off above the junction.

4. **Wooden wedges** with well-blunted points are often useful for tightening lashings. They are generally used by builders in scaffolding, and should be driven in at the top of the lashings.

5. **Hemp-rope lashings** soon become loose, and require frequent re-making. Wire lashings should be used in their place when possible.

evenly against each picket, driving a second row of pickets immediately in rear of the first row, and lashing the pickets as shown: the pickets should be at equal distances on either side of the centre of the baulk. The baulk is inclined by sinking the rear edge, in order to give a fair bearing against the pickets. Sufficient soil is removed to allow of straps or ropes passing round the baulk.

9. When a **buried log** (Plate **95**, Fig. 3) is used for large strains, a trench is dug long enough to hold the log, and the cable is given one complete turn round it and passed up through a narrow incline constructed at right angles to the trench. The running end is then seized to the standing part in two or three places. The slope of the cable or guy should generally not be steeper than 1/3. The method of calculating the depth of the trench and the precautions to be taken when using this anchorage are given in Military Engineering, Vol. III.

10. The form of anchor mentioned in Sec. **60**, **4**, i, and shown on Plate **66** makes a good holdfast, but its strength should be tested in the actual ground in which it is to be used.

Should it be intended subsequently to recover the anchor, a trip wire as shown in Plate **66**, Fig. 2, should be added. To recover the anchor, the stay wire is first slackened, and an iron rod or piece of piping passed down the hole. Three or four smart blows are given to the anchor so as to drive it back. This causes a cavity in the ground above the flukes, and a subsequent pull on the trip wire causes the flukes to re-enter the bore hole, and the anchor can be pulled out.

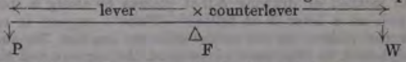
75. *Levers.*

1. A lever is a rigid bar capable of motion about a fixed point. The bar may be straight, as a handspike, or bent, as a claw hammer used to extract nails.

2. The point about which the lever turns is called the FULCRUM. The distances from the fulcrum to the points of application of the power and weight are called the **lever** and **counterlever**, respectively.

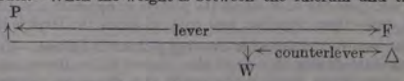
3. There are three orders of the lever.

First order.—When the fulcrum is between the weight and the power.



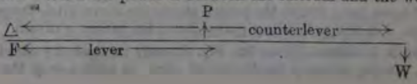
The handle of a lift pump is an example of a lever of the first order.

Second order.—When the weight is between the fulcrum and the power.



A wheelbarrow is an example of a lever of the second order.

Third order.—When the power is between the fulcrum and the weight.



A man raising a ladder or spar are examples of levers of the third order. In this case the ladder or spar is the weight, the power is applied by the man, and the ground at the foot of ladder or spar forms the fulcrum.

4. The power, P, required to raise a weight by lever is—

$$P = \frac{W \times CL}{L}$$

where L is the length of the lever, CL is the length of the counterlever.

76. *Strength and size of cordage, &c.*

1. The chief requisites of rope are strength, suppleness and durability: service ropes are made of hemp, manilla fibre, and coir: of these hemp is the strongest and most reliable: it is issued white or tarred.

Manilla stands exposure to weather and damp better than hemp, and does not kink so much, but cuts, where knotted.

Coir is very weak but light. It will float in water and does not rot: it is suitable for towing purposes.

2. Under a heavy stress a new rope exhibits a tendency to unlay itself, and so to twist: new rope must therefore be stretched before use.

To uncoil a new coil of hemp rope, pass the end which is at the core through the core to the opposite side and draw it out; the turns will then run out without kinking.

A new hemp rope, when subjected to its working stress, will stretch about one-twentieth of its length.

Cordage must be returned to store dry, and should not be coiled down in a wet condition.

3. The following precautions should be observed when working with cordage:—

i. Sudden or snapping stresses should not be allowed to come on a rope.

ii. A rope exposed to chafe should be "parcelled" by wrapping it in canvas well daubed with tar and bound with spun yarn.

iii. Ropes should as far as possible be kept from chafing against sharp edges by interposing rollers or handspikes.

iv. Rope which has been thoroughly saturated should not be exposed to a greater stress than two-thirds of what would otherwise have been its safe working stress.

4. The size of a rope is denoted by its circumference in inches, and its length is given in fathoms (a fathom is 6 feet). Cordage is usually issued in coils of 113 fathoms, and steel wire ropes in coils of 100 fathoms.

5. White rope new is 30 per cent. stronger than tarred hawser rope and 20 per cent. stronger than tarred bolt rope. White rope is also more reliable, since it is made of the best Italian hemp.

Rope when wet shrinks, and when thoroughly saturated is weaker than when dry. White rope may lose a third of its strength if soaked for two or three days.

6. **Working stress.**—If C be the circumference of a rope in inches:—

i. For unselected cordage, C^2 cwts.

ii. For white service rope in good condition, $2C^2$ cwts.

iii. For steel wire rope, $9C^2$ cwts.

The strength of cordage or steel wire rope when slung over hooks or fastened by knots is appreciably reduced; the safe holding power in such cases should be taken as two-thirds of the working stress.

7. **The strength of wire varies greatly; as a very rough rule it may be** taken that the breaking weight in pounds equals three times the weight per mile in pounds (Table 12, Appendix VII). This rule holds good for iron and hard-drawn copper wire, while steel wire may be taken as about twice as strong. A factor of safety of 4 must be used to find the safe working stress.

8. **Strength of lashings.**—The safe holding power of cordage lashings, is four-fifths of the working stress of cordage multiplied by the number of returns; with wire lashings, three-fifths of the safe stress of the wires. These factors are to allow for unequal straining of the cordage or wires.

Thus a square lashing gives four returns for each complete turn of the lashing so that a square lashing of four complete turns of $1\frac{1}{2}$-inch unselected hemp cordage has a strength of: —

$$\frac{4}{5} \times 16 \times \left(\frac{3}{2}\right)^2 = 28 \cdot 8 \text{ cwts.}$$

9. **Lashing a block to a spar.**—In this case the strength of the lashing must first be reduced by four-fifths in the case of cordage or three-fifths in the case of steel wire rope to allow for the unequal straining of the turns and then by a further two-thirds to allow for the sharp bends round the hook. Thus the number of turns of 2-inch unselected cordage required to lash a block having a pull of 1 ton to a spar is 1×20 divided by

$$\frac{4}{5} \times \frac{2}{3} \times 2 \times 2^2 \text{ or 5 complete turns.}$$

CHAPTER XI

BLOCKS, TACKLES AND USE OF SPARS

77. *Blocks.*

1. **Blocks** are used for the purpose of changing the direction of ropes or of gaining power.

They are called single, double or treble, according to the number of sheaves which they contain. The sheaves revolve on a pin, which should be kept well lubricated.

Snatch blocks (Plate 96, Fig. 1) are single blocks with an opening in one side of the shell, to admit a rope without passing its end through. This opening is closed by a hinged strap.

2. A **fall** is the name given to the rope with which the tackle is **rove.**

The **standing end** of the fall is the fixed end, the other the **running end.**

A **return** is any part of the fall between two blocks, or between the ends of the rope and any block.

To **overhaul** the tackle is to separate the blocks.

To **round in** is to bring them closer together.

A tackle is said to be **chock-a-block** when it is rounded in as far as possible.

To **rack** a tackle is to fasten two opposite returns together, so that the blocks may retain their relative position when the running end is let go.

3. A tackle is rove by two men, back to back, 6 feet apart; the blocks should be on their sides between the men's feet, hooks to the front and the coil of the rope on whichever side it is desired that the running end shall come off and near the block which is to have the greater number of returns. Beginning with the lowest sheaf of this block, the end of the fall which is to be the standing end is passed successively through the sheaves from right to left and then made fast.

4. To overhaul a heavy tackle :—

The block from which the running end comes off is made fast to some holdfast, a handspike is placed through the hook or shackle of the other block, and a drag-rope made fast to it.

To overhaul the tackle the handspike and drag-rope are manned, whilst one or two men overhaul the returns from the standing block.

Rounding in is the converse: the men on the drag-rope and handspike hang back, whilst a few others heave on the running end.

The handspike, both in overhauling and rounding in, is to keep the tackle out of the dirt, which would clog the sheaves.

5. In using tackle great care must be taken to prevent it from twisting. When both blocks are within reach the best method is to place a handspike at right angles, between the returns, close to the standing block, with a rope to each end, by means of which it can be steadied. When the movable block is out of reech the handspike should be lashed across it and a rope attached to each end.

78. *Tackles.*

1. Various tackles are shown on Plate 96. The simplest form of tackle is a **whip**—that is, a single movable block, rove with a rope, one end of which is attached to a holdfast, while the other is hauled on (Fig. 3).

When one tackle is bent to another, the total mechanical power is the product of the powers of the two tackles, *e.g.*, if a tackle giving a power of four to one is bent to a tackle giving a power of two to one, the total power gained is eight to one—thus the whip upon whip tackle (Fig. 2) gives a gain of four to one.

Theoretically in any system of two blocks the power required to raise a weight, W, is W divided by the number of returns at the movable block. An addition has to be made to overcome friction and resistance of the ropes to bending. Suitable tackles for most operations required in the field can be selected from Table 3, Appendix VIII.

2. The fall, in lifting heavy weights, can rarely be worked by hand, but has to be "**led**" to either a capstan or winch by which power is gained and a steady pull ensured.

3. In using tackles with sheers, gyns or derricks, the running end of the fall should always be led through a "**leading block**" lashed, as a rule, to one of the spars a few feet above the ground; a snatch block is most convenient for the purpose. (Plate 98, Fig. 4.)

4. Any slip of the fall round the barrel of the capstan or winch, called "surging," should be carefully guarded against, as it may increase the stress on the tackle and the spars as much as 50 per cent. If the barrel is slippery, or if working to a close margin, extra turns should be taken. Sand or grit should never be applied.

5. Steadying ropes or tackles should always be attached to the weight to keep it from swinging when raised.

6. Before using a tackle it should be seen that:—

   i. The straps, blocks and fall are in good condition.

   ii. The blocks are well lubricated and free from grit and dirt. No block in good working order should "complain," that is, make a noise.

   iii. The pins securing the hooks or shackles and sheaves of the block are made fast.

   iv. The standing end of the fall is properly made fast.

   v. The fall is free from kinks, runs freely over the sheaves and has a fair lead. Whenever possible the pull should be down hill.

7. During use it should be seen that:—

   i. When the fall is taut it is not jarred by being struck or by men treading on it.

   ii. The returns near the blocks are not touched when moving unless absolutely necessary, and then only those moving away from the block.

   iii. The stoppering of the fall, when necessary, is correctly carried out, and that the stopper is equal to the stress it will have to bear.

   iv. The position of the men is such that they will not be injured in the event of an accident.

v. When going round a curve the running end is led off so that the resultant strain is in the direction of travel.

vi. When a suspended weight is eased off it is done uniformly and not by jerks.

vii. In all cases when working near the safe limit of a tackle, before leaving a weight suspended, the tackle should be eased off slightly after raising or raised slightly after lowering.

8. Tackles should be carried and not dragged along the ground.

9. Two tackles should not be hooked into the same sling if it can be avoided.

10. Men should be taught to pull together silently. The fall should be **double banked** as this will keep the pull in a straight line. At the caution taut the slack is hove in, and at the word **heave**, they pull together and keep what they get.

79. *Standing derrick.*

1. A **standing derrick** is a single spar set up with four guys at right angles to one another, secured to the head with clove hitches (Plate 94, Fig. 6). A block for the tackle is lashed to the head and the derrick can be used for raising and swinging a weight into any position within its reach, which is about one-third of its height. The anchorages for the guys should be at a distance from the foot of the derrick equal to twice its height. The foot should be let into a hole in the ground to prevent it slipping and should rest on a bearing plate or shoe.

2. To raise a derrick, the spar is first laid on the line joining the footing and one of the guy anchorages, with the butt nearly over the footing. A foot-rope is secured to the butt and to a holdfast on the same side of the footing as the spar is on, and close to it. The four guys having been made fast to the head and passed to their holdfasts, the head is lifted as high as possible by hand. If the derrick is to be raised by the back guy, that guy is then hauled on and the fore guy let out until the derrick is in the desired position, the side guys being adjusted from time to time. Any guy may be used for raising provided it is strong enough.

3. In carrying a spar, the party should be equally divided on either side of it, and sized from one end. The spar should then be lifted in two motions on to the inner shoulders of the men. In lowering a spar the party should slowly face inwards, and lower first the butt end and afterwards the head. One man should always give the word for lifting and lowering.

80. *Swinging derrick.*

1. A **swinging derrick** consists of a standing derrick with a swinging arm attached to it near its foot. The head of this swinging arm is connected to the upright spar by a connecting tackle, and the main or lifting tackle is attached to the head of the swinging arm or jib (Plate 97). The upright spar is practically the same as a standing derrick, with the exception that as it will frequently be erected at the edge of a wharf or other place where it is not convenient to use a fore guy, a strut or struts must be used instead. A good method is to use two struts each about half as long again as the upright spar, lashing the three together as in a gyn (Plate 98, Fig. 3), and

then to erect it so that the standing derrick is vertical and the two struts are at right-angles in plan, and situated symmetrically with respect to the edge of the wharf. Two guys can also be used, one over each strut in plan, but secured to holdfasts at the customary distance; or three guys can be used, one a back guy and the other two side guys, but set back about 20° from the edge of the wharf, to allow room for the loads to be landed. It is important that these guys should not stretch too much, so that the upright spar may remain vertical. It is, therefore, better to make them of wire rope, and in any case a tackle should be included in them to take up any slack. The stress in these guys is much greater than that in guys for a standing derrick to deal with the same weight.

2. The jib is most conveniently formed of two spars lashed together at their head, and separated at their butts to a distance about equal to the diameter of the upright spar. They are lashed about 12 or 18 inches from their butts to a stout cross-piece, and the end thus formed encircles the butt of the upright (Plate **97**). The jib is supported by a length of chain secured at its centre by a clove hitch round the upright, and prevented from descending by a collar of rope, and each end secured to one of the arms of the jib. The latter is enabled to swing under the control of two side guys or reins attached to its head. The length of the jib may be of the same length as the upright. The inclination of the jib can be altered by the connecting tackle, and the radius of its circle of operation is thus determined, but the angle between the jib and the upright should not exceed 75 degrees. The weight can be lifted or lowered by the main tackle and the jib swung by the guys. The jib can only be swung right over the edge of the wharf on that side of the upright on which are the leading blocks of the main and connecting tackles. If it is necessary to swing both ways, duplicate leading blocks for the falls of these tackles must be provided.

3. It should be noted that the weight must be allowed to hang vertically from the head of the jib. If it is hauled towards the butt of the standing spar, the thrust on the jib is greatly increased; if it is hauled away from this butt, the stresses in the back guy and connecting tackle are largely increased. If the weight has to be brought in otherwise than by swinging to a flank, it should be done by raising the head of the jib by means of the connecting tackle.

4. The number of men required to erect derricks to lift weights up to 4 tons is from 20 to 25.

81. *Sheers.*

1. **Sheers** require only two guys—"fore" and "back." They should be fastened to the legs above the fork by clove hitches, the back guy to the fore spar, and *vice versa*, so that their action may tend to draw the spars closer together and not strain the lashing (Plate **98**, Fig. 2). The minimum distance of the anchorages from the legs should be double the height of the sheers. The upper block of the tackle is hooked to a sling of rope or chain passed over the fork. Sheers can, as a rule, be used for heavier weights than derricks, but can only move them in a vertical plane passing between the legs. The feet of sheers must be secured or let into holes in the ground. The distance apart of the legs should not be more than one-third the length of the leg up to the fork, and the sheers should not be heeled over more than one-third of their height.

2. In order to lash the legs they are laid side by side on a skid, and kept 2 inches apart by a wedge. The lashing is commenced with a clove hitch on one spar, carried six or more times upwards round both spars without riding, then two frapping turns, and finished off with two half hitches round the other spar (Plate **98**, Fig. 1).

82. *Gyns.*

1. A **gyn** consists of three spars lashed together at the tips, the butts forming an equilateral triangle on the ground. It requires no guys but can only be used for a vertical lift.

2. In order to lash the legs, the spars are laid on a skid, a clove hitch is made on one of the outside spars, and the lashing taken loosely over and under the three spars six or eight times: frapping turns are taken round the lashing between each pair of spars, finishing off with two half hitches on the other outside spar (Plate **98**, Fig. 3).

3. The two outside spars (cheeks) are then crossed until the distance between the butts equals half the length of the leg: a ledger is lashed across these two spars about 1 foot from the ground. The gyn is then raised by using the centre spar as a "prypole," and the two remaining ledgers lashed on.

4. Many varieties of "service" gyns are available: of these one of the most useful is known as the gyn, triangle, light, to raise $2\frac{3}{4}$ tons; this gyn weighs 2 cwts., is made of steel and consists of two cheeks, 13 feet 3 inches long, a prypole, and a shackle connected by a headbolt and a 3-ton differential tackle. The cheeks have loops at their lower ends for a bracing rope. When erected for use, the cheeks should be 8 feet apart, and the foot of the prypole 12 feet from the cheeks.

5. **Points to be observed when working with gyns :—**

i. The prypole is always considered to be the front.

ii. The foot of the prypole should be equidistant from the feet of the cheeks.

iii. All three feet should be on the same level and properly supported. If, as sometimes happens, the prypole has to be lower than the feet of the cheeks the maximum load put on the gyn must be considerably reduced.

iv. The height of lift can be increased by placing the feet on planks or skidding.

v. The gyn should be placed with its head over the centre of gravity of the weight to be raised, except where a swinging lift is required, when the head of the gyn should be over a point midway between the points at which the weight has to be picked up and lowered.

vi. A suspended weight can be hauled straight towards the centre of the cheeks or towards the prypole without risk of upsetting the gyn, but hauling it to either flank or taking a swinging lift is liable to cause the gyn to capsize and should only be done with the greatest caution. In no case should the lower block be allowed to come outside the line joining the prypole and cheek. If a considerable swing is required light side guys should be attached to the head of the gyn, or the cheeks lashed down to prevent them rising.

vii. Before taking the weight, the foot of the prypole should be lashed to the cheeks.

viii. A gyn should not be left standing on pavement, concrete, or any smooth surface, though there may be no weight suspended, without securing the feet from slipping.

83. *Size of timber, tackles and ropes for derricks, &c.*

1. The design of derricks, sheers and gyns depends on the weight, the height to which it is to be lifted and the stores available. The length of the spars must be sufficient to allow for the length of slings and for blocks becoming chock in addition to the height which the weight has to be lifted. A tackle when chock-a-block will occupy 4 or 5 feet.

In the case of derricks and sheers the distance from the base at which the weight has to be picked up may determine the height, since this distance must not exceed "one-third" of the height.

2. The stresses in individual members are best determined graphically, but as this is not always possible, Tables, 1, 2, 3 and 4 are given in Appendix VIII, from which suitable spars, ropes and tackles can be selected.

3. Example.—*A weight of* 3 *tons has to be lifted* 6 *feet and moved* 4 *feet horizontally.*

Compare the principal stores required for doing this with sheers and with a standing derrick.

The minimum height of either sheers or derrick to the point of attachment of the main tackle is $4 \times 3 = 12$ feet. This will be sufficient to raise the weight 6 feet allowing for tackle and slings. In both cases the main lifting tackle is the same, viz., two treble blocks with $1\frac{1}{2}$-inch wire rope (Table 3).

For sheers the stresses are :—(Table 1).

In leg with leading block ...	$3 \times 1{\cdot}2 = 3{\cdot}6$ tons ∴ use $8\frac{1}{2}$-inch spar (Table 2).
In other leg	$3 \times 1 = 3$ tons ∴ use 8-inch spar.
In back guy	$3 \times {\cdot}7 = 2{\cdot}1$ tons ∴ use one single and one double block with $1\frac{1}{2}$-inch wire rope (Table 3).

For a derrick the stresses are :—

In spar	$3 \times 2 = 6$ tons ∴ use 10 inch spar.
In back guy	As for sheers.
In other guys	$3 \times {\cdot}3 = {\cdot}9$ tons ∴ 3-inch cordage used double will do (*see* Sec. 76, 6).

NOTE.—From the tables square baulks and other systems of tackles can readily be selected to suit the stores available.

Sec. 84, 6, *Approaches*—

6. The construction of any bridge includes the approaches to and from it. The approach roads to heavy bridges on the main routes of traffic of an army require special attention, and in some cases new approach roads of considerable length may have to be built, to give access to bridges which may, necessarily, have to be sited at a distance from existing roads.

New approaches and roads will usually have to be made to all pontoon bridges, and the time involved may often exceed that required to construct and launch the bridge itself.

It is essential, therefore, that careful previous arrangements shall have been made in regard to labour, material and transport to ensure the earliest use of the bridge.

CHAPTER XII

ROAD BRIDGES AND THE PASSAGE OF GAPS

84. *General remarks.*

1. Engineers will be called upon to assist troops in the crossing rivers, streams, &c., over which insufficient means of passage exist or where bridges have been destroyed by the enemy.

Such engineer work will usually come under the following headings :—

- i. Reconnaissance and passage of the advanced patrols.
- ii. Construction or repair of bridges with materials found locally.
- iii. Construction of bridges with bridging stores held in stock in the theatre of war (*see* para. 3 below).

2. Military bridges are classified, according to the load they are designed to carry, as follows :—

- i. Light bridges.—
  - (*a*) Foot bridges.—For infantry in single file.
  - (*b*) Pack bridges.—For infantry in file, cavalry in single file, pack artillery and pack transport.
- ii. Medium bridges.—For infantry in fours, cavalry in half-sections, horse transport, motor cars, armoured cars, light and medium artillery, 3-ton lorries, all ordinary M.T. up to a limit of 5½-ton axle load, and track vehicles up to 8 tons in weight and not exceeding 8 feet 9 inches in width.
- iii. Heavy bridges.—For heavy artillery, tractors, other M.T. vehicles in excess of medium loads up to a limit of 16-ton axle load, and tanks up to 18 tons.
- iv. Super-heavy bridges.—For axle loads and tanks in excess of the above loads.

3. Bridging equipment and stores are carried or held in stock as detailed below :—

- i. With a field park company—two trestles and three 21-feet bays of superstructure for medium bridge.
- ii. With the corps pontoon park—pontoons, trestles and superstructure, which can be formed up either into medium or heavy floating bridges.
- iii. In the engineer store depot at the base—
  - (*a*) Light floating bridges.
  - (*b*) Steel super-heavy bridges.

4. It is the duty of the corps staff to send forward as much of the pontoon bridge park as may be necessary to the points decided for crossings, to ensure its timely arrival and to arrange for the provision of any tractors that may be necessary to haul the trailers from the road to the site of crossing. It is further the duty of the corps staff to arrange with G.H.Q. for timely despatch from the base of any light floating bridges which may be necessary for the passage of a

stream in battle, and also for the despatch of such super-heavy bridges as may be necessary.

5. It is normally the duty of the divisional engineers to construct :—

i. Light bridges for infantry and pack artillery in the attack.
ii. Medium bridges for the remainder of the divisional artillery and divisional transport.

The engineers of any formation may be required to construct heavy or super-heavy bridges.

(For para. 6, approaches, *see* page 106.)

7. The following tactical principles affect the work of the engineers in the passage of rivers :—

i. The initial crossing by infantry advanced parties should be arranged to take place at many points simultaneously, and usually well away from the known and marked favourable crossings, which will almost certainly be covered by artillery and machine-gun fire.

ii. To enable infantry and pack artillery to cross a river in the attack, the divisional engineers must provide one or more of the following :—

(*a*) Improvised ferries.
(*b*) Improvised light bridges.
(*c*) Light bridges (or ferries) formed of the standard floats and superstructure sent up from the base.

iii. When an adequate bridgehead has been secured, it will be necessary to construct :—

(*a*) Medium floating bridges.
(*b*) One or more heavy floating bridges (if tanks accompany the division),

to enable the divisional artillery and transport to follow up and support the infantry.

These bridges should be constructed as near to the normal road crossings as the river banks will permit, in order to reduce cross-country haulage of trailers.

iv. When large bodies of troops have to cross a river, separate bridges will, whenever possible, be provided for up and down traffic, and road traffic circuits arranged accordingly so as to avoid congestion at the bridges.

v. The staff will arrange, when necessary, for forming-up places away from both banks of the river. That on the near bank will be used for marshalling the traffic prior to crossing the river, and that on the far bank for assembling units after the crossing.

8. It is desirable that bridges formed of pontoon equipment should be replaced by improvised or by steel bridges as soon as possible in order to free the pontoon equipment for use elsewhere.

Light bridge equipment used in the attack will be salved for re-use, and should be returned to the base when no further immediate use for it is foreseen, in order to reduce transport in the forward area.

85. *Forcing a crossing.*

1. In the warfare of the future, especially when tanks are employed, there can be little doubt that a more extended use will be made of physical obstacles, more particularly canals and rivers, to hamper or prevent the employment of tanks.

Surprise is the essence of success in operations involving the passage of water obstacles, and therefore governs all preliminary steps taken prior to the attack.

The enemy must be kept in ignorance of the points of crossing. All preliminary preparation must be carefully concealed, reconnaissance parties must move with the greatest caution and every effort made to deceive the enemy. Obvious crossing places, which are easily and quickly bridged, may often be more difficult to cross on account of the enemy's fire than wider and less easy ones.

The actual crossing will probably be carried out at night, or under cover of smoke screens. Some light is essential, and dawn or when the moon is obscured by clouds are suitable times. With tidal rivers, the time of high or low tide may be the ruling factor.

2. The time required for preparation necessary to achieve success will vary, but it is most unlikely that more than a few hours will be available in mobile warfare: a high state of training in and knowledge of bridging operations by all ranks is, therefore, essential.

3. As far as time permits, information must be obtained on the following points:—

Nature and width of gap; strength of current; nature and slope of banks; approaches; possibility of deployment of attacking troops on far bank; cover for bridging material on near bank; positions for covering fire by rifle and machine guns; the presence and width of any subsidiary channels or obstacles which would have to be bridged; and, if a tidal river, the rise and fall of the tide.

This information will be obtained from large scale maps, aeroplane photographs, both vertical and oblique, and ground reconnaissance carried out at dawn and dusk.

4. Forcing the crossing of a canal or river line is a tactical operation for which the commander of the unit or formation which has actually to force the passage is responsible. It is for him to decide the sites for the bridges and where the bridges are to be put together, having due regard to the technical requirements as represented by his technical adviser, the engineer commander. The officers responsible for carrying and launching each bridge will be detailed by name.

5. It is essential that the reconnaissance for the bridging sites should be carried out by officers of the assaulting troops, accompanied by an engineer officer if available.

6. Sufficient time should be allowed for covering parties to get into their allotted positions in order that there should be no danger of detection through the necessity for hurried movement.

Covering parties should be in position before the bridges are pushed across. They should not rush to their positions simultaneously with the bridge-carrying parties.

Should the covering party have to open fire to protect the launching of the bridges and the passage of assaulting troops, it must open the heaviest volume of fire possible.

Flanking and overhead fire from automatic guns will be of great value. This fire should be supplemented by that of artillery to neutralize those areas from which the enemy can bring direct fire to bear on the crossings.

In addition, smoke may be of assistance in mystifying the defence as to the exact points of crossing.

7. The method of crossing depends on the width and nature of the channel. With narrow rivers and canals, assault bridges can be pushed across. With wide rivers it may be advisable to send forward a covering party on rafts on a wide front just before launching the assault bridges. With large rivers and estuaries, ferries and armoured gun-boats may be the only means of crossing.

The number of assault bridges depends on the width of the channel, the material and labour available, and the tactical situation.

8. Tapes should be laid from the forming-up line to the crossings beforehand, or, if the gap cannot be reached by the bridging parties, unrolled as they advance. Illuminated signs should be provided on the forming-up line by night: lights in petrol tins, pierced with small holes, are suitable, as they cannot be seen from aeroplanes.

9. The leading troops detailed to cross by the assault bridges (unless the carrying party is detailed for this duty) should remain under cover until the assault bridge is secured on the far bank and ready for crossing. They should then cross as rapidly as possible.

Under no circumstances should the assaulting troops follow the bridge-carrying party so closely that they have to halt on the bank and wait for the bridge to be launched.

10. It must be remembered that darkness greatly increases the difficulty of bridging operations, and also the time which must be allowed for preliminary reconnaissance and selection of bridging sites.

11. The importance of traffic control cannot be over-emphasized. During assault bridging operations, congestion is very liable to occur, especially on the near bank.

In order to avoid congestion, a careful system of control posts and connecting files is necessary, so as to ensure that the forward movement of troops can be properly regulated and, if necessary, stopped altogether should the situation at the bridges demand it.

One infantry officer will be detailed for each assault bridge to ensure that troops do not bunch in the immediate vicinity of the bridges before crossing.

The officer commanding the engineers will arrange for all engineer personnel except a minimum maintenance party (see para. 13 below) to clear away from the bridges as soon as they have been launched.

In addition to the actual control by an officer of each body of infantry moving up to the bridges, a staff officer will be detailed for each brigade series of crossings to control the advance of units towards the bridges.

12. Arrangements must be made so that in the event of failure to launch a bridge, or its destruction by fire, it will be possible to divert the troops detailed to that bridge to other bridges which have been successfully launched.

13. In order to keep bridges in action, a maintenance party and, if possible, 50 per cent. of spare material will be required. A party must be detailed to keep watch above the highest upstream bridge to divert and bring to the bank floating objects such as mines or debris, which would break the bridges downstream.

86. *Selection of the exact site for a bridge and measurement of the gap.*

1. **The selection of the exact site** for a bridge depends on the tactical situation and probability of enemy fire, the nature of the banks and approaches, the nature of the bed, the width to be bridged, the depth of the gap, and, when there is water, its depth, the strength of the current, the probability and extent of floods, and, if a tidal river, the rise and fall of the tide. The headway to be allowed over a road or railway is 12 feet 6 inches; that over a canal varies in different countries, but is generally about 12 feet 6 inches. In navigable waterways provision must be made for a "cut" of 20 feet in floating bridges, or alternately for a swinging bridge.

2. The **approaches** at both ends of the bridge are of paramount importance, to obviate any crowding on the bridge. Approaches, other than those consisting of properly metalled road, cut up very quickly, and, if neglected, become almost impassable in wet weather: some form of roadway, sleeper or corduroy (*see* Sec. **110**), must be laid down. Timber approaches have the advantage that animals get accustomed to the sound before coming on to the bridge. Approaches must be made up so that there is no impact or bump when vehicles pass from the approach on to the bridge.

When ramped approaches are necessary, the slope for animals and wheeled vehicles should not be steeper than 1/10; in ramping down on to a bridge, the approach should be level for 3 or 4 yards immediately before the bridge in order to lessen the impact.

Except in close proximity to the enemy the approaches must be clearly outlined by stout pickets painted white; tracing tapes must be used where this is impossible.

3. **Section of the gap.**—As soon as the site has been fixed, a section will be made to determine the type of bridge which best suits the gap, and the gap will be divided into spans according to the material available for bridging.

A section is taken as follows:—

A string or rope, marked into these spans with knots of white tape, &c., is stretched as taut as possible across the gap at "shore transom" level, and a section of the gap obtained by using a pole marked in feet and inches. If the rope has much sag the method shown on Plate **99**, Fig. 1, must be adopted.

When taking the section of rivers, canals, &c., if no boat is available, something must be improvised to support the man holding the pole. The single barrel raft (Plate **111**, Fig. 2) and the bivouac sheet boat (Plate **118**) are examples.

For bridges with floating piers nothing more is necessary; the section will show any place where there is insufficient depth of water to float the piers when the bridge is under its maximum load. In such places fixed piers must be built.

For bridges with fixed piers the mean vertical height of each pier from the foundation or "footing" to the level of the shore transom is found from the section; to this height must be added:—

i. An allowance for "camber" (*see* Sec. **87**, 3).

ii. An allowance for "splay" when the piers are trestles with splayed legs; this splay equals 1 inch in 6 feet along the length of the trestle leg.

iii. An allowance for soft bed, if the bottom is muddy; a trestle, in soft mud, providing "shoes" (*see* Sec. 90, 4) have been fixed, will not sink more than 12 inches. If the bottom is very uneven a section for each side of a trestle bridge will be required.

87. *General description of bridges.*

1. **Types of bridges.**—Bridges, of whatever nature, may be divided into four types:—

i. Single span bridges.
ii. Non-floating type.—Bridges with intermediate fixed piers, such as trestles, crib piers, piles, &c.
iii. Floating type.—Bridges with intermediate floating piers, such as barrel piers, log piers, boats, &c.
iv. A combination of ii and iii.

2. **Parts of a bridge.**—A bridge consists of a roadway carried over an obstacle, or, as it is called, a gap, and with, where necessary, one or more intermediate supports, called piers. The gap may be wet or dry. The distance between any two piers is called a "span" or a "bay"; the length of a bridge from shore to shore is called the "total span."

The parts of a bridge described in the following paragraphs are those of a "light" bridge. Medium and heavy bridges are dealt with in Military Engineering, Vol. III.

3. The **roadway** (Plate 99, Fig. 2) consists of decking carried on roadbearers or baulks, which rest on transoms (the top beams of the piers): the decking is held down by ribands or wheel-guides.

The normal **width of roadway** in the clear between ribands is 9 feet.

The roadway is generally constructed with a slight rise towards the centre of the bridge to get loads on to the bridge quietly and easily and to assist traffic off the bridge; this is technically called the **camber**, and is obtained by giving a rise of 1 in 30 for about 30 feet from each end of a bridge.

4. **Decking** should consist of planks 3 inches thick, but 2-inch hard wood (beech) road slabs may be used if available. In all decking there should be ½-inch spaces between the planks to allow for drainage; the planks are nailed to the outer roadbearers. The decking should not project more than a few inches beyond the outer roadbearers. For horse traffic, straw, rushes, &c., must be laid on the decking. Battens or earth must not be used; the former are easily knocked off and leave nails which lame horses, while the latter becomes very slippery and blocks drainage.

5. **Roadbearers** may consist of timber in scantling, round logs, rolled steel joists, rails, &c. The number and size of the roadbearers for any span may be obtained from Table 5, Appendix VIII.

Roadbearers are spaced evenly over the width of the roadway; if they differ in strength, the strongest should be placed beneath the wheel tracks. The outer roadbearers should be spaced 9 feet apart in the clear. In many bridges the roadbearers of adjoining bays overlap on the transom; they should therefore be from 2 to 3 feet longer than the span. When round spars are used, the ends on any transom must be all butts or all tips. Roadbearers should be spiked to the transoms, when tactical conditions permit; otherwise lashings of wire or cordage may be used; chocks should be fixed on the transom between the roadbearers to keep them in position.

6. **Transoms** carry the roadbearers and must be adequately supported. For bridges with spans up to 15 feet, round logs of 8 inches average diameter, or 6 inches by 6 inches squared timber, form suitable transoms if supported as shown on Plates **100** and **101**; if carried on two supports only they must be considerably heavier (Plate **102**). A transom should project sufficiently far on either side of the roadway to allow of the fixing and strutting of handrails (*see* para. 8 below).

A bankseat or shore transom must be provided on either side of the gap to support the shore-ends of the roadbearers. A 9-inch by 3-inch plank, laid flat, makes a suitable shore transom (Plate **99**, Fig. 3); care must be taken that the plank "bears" throughout its length, and that it is securely anchored. It must be placed at a sufficient distance from the edge of the gap to prevent the soil breaking away under the pressure—this distance should never be less than 1 foot (in chalk, &c.) and may be 3 or 4 feet; if the sides of the gap are liable to collapse, they must be revetted.

7. **Ribands or wheel-guides** hold the decking together, and prevent the traffic going off the bridge; they should consist of 6-inch round logs, or 6-inch by 6-inch squared timber spiked to the decking immediately above the outer roadbearers. The ends of adjoining wheel-guides should either butt or be halved into one another. Wheel-guides should be painted white, and the shore ends splayed to facilitate the approach on to the bridge. A heavy bumping post, well let into the ground, is useful at the extreme end of the wheel-guide.

8. **Handrails** (4-inch round timber or 6-inch by 3-inch scantlings) should be fixed to all bridges, except when they would disclose the position of the bridge to enemy ground observers; they should be 3 feet above the decking, and at least 9 inches clear of the inner edge of the wheel-guides, the posts being fixed on the transoms and strutted (Plate **100**). These posts must not be less than 4 inches in diameter and should be painted white. Screens of canvas or branches, 6 feet high from the decking, should be securely fastened to the handrails to prevent animals seeing the water or the depth of the gap below them. Flapping screens are worse than none.

9. The best **fastenings** for bridge work are iron fastenings, but wire or rope lashings may have to be used; the latter are difficult to obtain, and are the least satisfactory, owing to the difficulty of keeping them taut.

Iron fastenings may consist of dogs, spikes, drift-bolts, nails, bolts, chains, &c. With dogs the position of each must be chosen with the definite object of preventing a possible distortion of the frame. They should be on both sides of the frame. Dogs should not be driven within 3 inches of the edge or 4 inches of the end of a piece of timber.

Spikes, when driven in pairs, should incline towards each other. They run from 5 inches to 10 inches in length (Appendix VII, Table 13). Spikes with chisel points should be driven so that the edge is across the grain.

Drift-bolts are made of round iron, pointed at one end and with a small head at the other. They may be of any length, and are especially useful for fastening horizontal timbers to the top and bottom of upright timbers. Holes slightly smaller than the bolts should be bored to receive them.

10. On the completion of the bridge the officer in charge of the construction is responsible that:—

i. The bridge is strong enough for the loads which it is intended to carry.

ii. **Conspicuous notice boards** are erected at either end of the bridge stating what loads the bridge will take; these notice boards must be supplemented by similar notice boards sufficiently far back on the roads leading to the bridge to allow of traffic, too heavy for the crossing, being directed elsewhere. Arrangements must be made to illuminate the boards at night. "Break step" notice boards must also be erected at either end of the bridge.

iii. A maintenance party of adequate size is left to maintain the bridge. This party will improve the bridge, maintain the approaches, and police the traffic pending the arrival of military police. He will ensure that this party knows how to communicate with him, and that it is not withdrawn without definite orders from the higher command.

iv. Material is available on the spot for repairs, that arrangements have been made to bring up such material, or that the maintenance party knows where to obtain it.

11. **Gauges.**—Whenever there is water in the gap, a clearly marked gauge must be established, so that any rise or fall of water may be detected.

88. *Light bridges—infantry footbridges.*

1. Infantry footbridges may be extemporized from planks with or without intermediate supports, but it is best to provide light portable bridges made up either as single spans or, if more than one span is required, in two parts—(*a*) the roadway section; (*b*) the pier section.

If there are "n" piers, there will be "n + 1" roadway sections. Such a bridge must be designed so that it or any one of its component parts can be carried by not more than four men over 1,000 yards of rough country in the dark without undue exertion, and that it is simple to assemble, or put together.

2. **Single-span infantry bridges.**—The simplest form is a plank: a 9-inch by 2-inch plank, 10 feet long, will take two armed men at a time over a gap 8 feet wide. Two planks should be placed side by side to give a roadway of 18 inches. For gaps 8 to 15 feet in the clear, some sort of trussed beam or a light plank footbridge is necessary. Plate **103** shows a trussed beam footbridge, but bridges of this type must only be used over the exact span for which they are designed, as otherwise they become distorted and dangerous.

A light plank footbridge may be constructed as shown in Plate **104**. The road-bearers are prevented from falling over sideways by two turns of hoop-iron or twisted wire wound over and under alternate roadbearers and securely nailed to their upper or lower sides. The roadway should be covered with wire netting or grillage. Great care must be taken to get a level bearing surface for the shore ends, or the bridge may take a tilt, and quickly become useless. See also Plate **110**, Fig. 2.

3. **Infantry bridges with fixed piers.**—The piers may be light two-legged or four-legged trestles or light piles. These bridges have the following disadvantages:—the trestles are difficult to handle and place in the dark, and, when previous reconnaissance is impossible, the adjustment of the transoms takes time; they are very liable to distortion when the weight comes on them. The construction of light-pile piers involves considerable time and noise.

4. **Infantry bridges with floating piers** are the best method of crossing streams over 14 feet in breadth. A standard type with Kapok floats is made for use in the field (Plate **105**). If this bridging equipment is not available, improvised bridges can be made with petrol tins or cork slabs. If the standard metal fittings of the Kapok bridge equipment are available, an improvised bridge built up with petrol tins can be made as shown in Plate **106**.

Plate **107** shows an alternative method in which the standard metal fastenings are not used.

If properly constructed, these bridges are stable and a level roadway is ensured; they can be placed in position in a very few minutes by trained personnel.

The roadway consists of special light trenchboards with bearers arranged so as to interlock on the saddle of the float, and be pinned together.

To give lateral rigidity so that the bridge can be boomed out rapidly across a river with a current, wire ties may be fastened from the end of the piers to the centre of the trenchboards on either side Two men should be on the front end of the bridge; on reaching the far bank they will lay the shore bay and secure the mooring rope. Where there is little current one mooring rope passed through the rings on the ends of the piers, and made fast to pickets on each bank, may suffice to hold the bridge in place; but additional mooring ropes, or anchors, will be needed where there is much current.

Casks or plank footbridges (Plate **108**) may often be useful, but take rather longer to construct.

The catamaran bridge (Plate **111**) is another useful type of a light foot bridge.

5. Approximate weights of component parts of some of the bridges described above, are as follows:—

	lbs.
i. Trussed beam bridge 10 feet long (Plate **103**)...	50
ii. Petrol tin pier with saddle (Plate **107**)	110
iii. Kapok pier with saddle (Plate **105**)	80
iv. Pier of cask footbridge (Plate **108**)	350
v. Pier of single cask footbridge (Plate **111**)	220

89. *Light bridges—single span.*

1. Small gaps may be filled in (Sec. **109**, 7) or bridged by laying roadbearers, selected according to the span from Table 5, Appendix VIII, across the gap, resting on bankseats and supporting 3-inch decking.

2. **"Artillery" bridges** are portable bridges, consisting of two longitudinal sections of roadway, designed to enable a battery to cross a small gap (Plate **109**). They are not intended for continuous traffic.

3. **Cantilever and suspension bridges.**—When the gap cannot be spanned by the above methods, and neither a trestle bridge nor a floating bridge can be used (as in crossing a ravine with deep precipitous sides), recourse must be had to a cantilever (Plate **112**) or suspension bridge. It will only be on rare occasions that such bridges will be required. Both forms of bridge take a longer time to construct than either floating or trestle bridges.

Details of suspension bridges are given in Chapter VII, Military Engineering, Vol. III.

90. *Light bridges—non-floating type.*

1. **Fixed piers** may be made of an infinite variety of materials, *e.g.*, brushwood cylinders, or wooden crates, filled with stones, carts, &c., but the material most likely to be available is timber; this may be used in the form of crib piers or trestles.

2. **Crib piers.**—When timber is plentiful, crib work (Plate **109**) is useful and speedy up to a height of 4 feet; if sleepers are available and close at hand, piers up to 7 or 8 feet are economical in time. In water, a tray should be formed in the bottom of the cribs and filled with stones. These piers, if necessary, can be floated into position and sunk by loading the trays, but if the bottom proves to be very uneven it will be difficult to keep the piers vertical. Figs. 4 and 5 on Plate **109** show a crib causeway, which was constructed during the Great War, to enable tanks to cross a small river. As all the structure was below water level, the existence of the bridge was concealed from the enemy before it was used.

3. **Trestles** are the most useful form of fixed piers. The best are those which are framed together with the transom resting on the head of the legs. When using squared timber all joints should be flush; tenons, notches, &c., are unnecessary and detract from the strength of the timber.

A framed trestle is shown on Plate **100** suitable for bays of light bridge up to 15 feet and for a height of trestle up to 12 feet. It weighs about 12 cwts. and is easily handled. It can be used for height of trestle up to 15 feet by using four 6-inch by 6-inch legs evenly spaced, or three legs 7-inch by 7-inch. A similar trestle can be made out of round spars, but in this case the timber must be notched to get a bearing surface and 8-inch round spars must take the place of the 6-inch by 6-inch scantlings with 4-inch braces, and the trestle will be somewhat heavier.

A plank trestle can be made of similar type as shown on Plate **101**. In this case all the joints are nailed and the legs are hollow, but are packed solid where the braces are nailed to them. The planks forming the legs are nailed together and should be bound with hoop iron every 3 feet. A trestle of the dimensions shown is suitable for bays of light bridges up to 15-foot span and for a height of trestle up to 12 feet.

Framed trestles require a level foundation and the height of transom cannot be readily adjusted when the trestle is in place.

When the bottom is uneven and cannot be levelled a type of trestle with two legs only must be used, the ledger being placed high enough to clear any obstruction. In this type the joints are usually made with lashings of wire or rope, which allow of a certain adjustment of the height of transom when the trestle has been launched, and the legs extend above the transom to take a hand rail. Lashings, however, require constant attention and are only suitable for temporary bridges.

A trestle of the dimensions shown on Plate **102** is suitable for bays of light bridges up to 15 feet, and height of trestle up to 15 feet.

The transom, the ledger and the butt of one of the braces are on the same side of the legs, the other butt and the tips of the braces are on the opposite side. All lashings are "square" except when the braces cross, when a diagonal lashing is used. The trestle must be squared by making the diagonals equal before the braces are finally lashed.

4. **Ledgers and shoes.**—When the bottom is soft, the ledger is placed near the bottom of the trestle legs. When the bottom is very soft, arrangements must be made to prevent the trestle sinking by placing horizontal timbers at the feet of the legs, or by furnishing them with flat shoes about 15 inches square of 1½-inch planking, spiked to the feet of the trestle legs.

5. **Placing trestles.**—If the gap is wet, trestles can be carried out and placed by men working in the water. When the water is too deep for this, they may be carried on to the bridge and lowered feet first down inclined spars (Plate **110**, Fig. 1), or taken out on a raft and tipped into position by means of guys.

6. Trestles are kept vertical by fastening the roadbearers to the transoms, and by cross-bracing from each trestle to its neighbours. When using lashed trestles, the nearest trestles to the bank on either side should be rigidly connected to bollards on the banks by light spars fitted to the legs about 3 feet above the transom. These light spars are put on before the trestle is launched, and help to get it into position, and must be secured before the first bay is used for placing the second trestle.

7. **Scouring.**—The presence of a pier in running water previously unobstructed causes an underscouring action by the water to commence on the upstream side of the pier, which may eventually capsize the pier.

This can be temporarily guarded against by surrounding the up-stream side of the pier with boulders or sacks of small stones, but the waterway (Sec. **91**, 1) must not be obstructed.

91. *Light bridges—floating type.*
(*For buoyancy see* Sec. **94**)

1. **Floating piers,** in the absence of pontoon equipment, may be constructed of casks, boats, logs, &c. Each pier must have enough available buoyancy to support the heaviest load that can be brought on to one span of the bridge. The length of each pier should be twice the breadth of the roadway for the sake of steadiness, and with the same object, they must be connected together at their ends by tie baulks (Plate **114**). The waterway between the piers should never be less, and should, if possible be more than the width of the piers.

2. A bridge can be put into position in the following ways:—

i. By **booming out,** *i.e.*, when the head of the bridge already constructed is continually pushed out into the stream fresh materials being added at the tail. This method cannot be used with steep banks and deep water close in shore.

ii. By **forming up**, *i.e.*, when material is continually added to the head of the bridge, the tail being stationary. This method is uninfluenced by the nature of the banks, no men being required to work in the water. Its only drawback is the distance the roadway materials have to be carried.

iii. By **rafting**, *i.e.*, when the bridge is put together in different portions, or rafts, along the shore, each raft consisting of two or more piers, and these rafts are successively warped, rowed or towed into their proper positions in the bridge.

This method has the advantage that a large number of men can be employed simultaneously, and, if secrecy be an object, the various portions can be constructed at some distance from the eventual site of the bridge, and a favourable opportunity seized for its construction.

iv. By **swinging**, *i.e.*, when the entire bridge is constructed alongshore, and then swung across with the stream.

A long bridge can be constructed by a combination of two or more of the above methods.

3. The **bridge ends** to floating bridges require careful consideration. In tidal rivers, and in non-tidal rivers, when the effects of droughts and floods may cause considerable variations in level, much ingenuity, time and labour are required in order that the bridge may be available at all times for traffic (Military Engineering, Vol. III).

A floating pier should not be allowed to ground, as it will be liable to be crushed when a load comes upon it. If it has to ground, it must be built of large barrels and the bottom levelled, or a cradle made of reeds, brushwood or sacks of earth.

4. **Anchors.**—As a rule, there should be an up-stream and down-stream anchor to every second pier of a floating bridge: in tactical operations under fire there must be an up-stream anchor to every pier.

For ordinary bridge work 56-lb. anchors, with a reserve of 112-lb. anchors, will generally suffice for moderate streams. The following substitutes may be employed:—Two or more pick-axes lashed together; heavy weights, such as large stones or rails (the latter are best when bent) (*see* Plate **119**).

The cables are generally of 3-inch cordage. The length of cable "out" should be ten times the depth of the stream, and rarely less than 30 yards. The cable is attached to the ring of the anchor by a fisherman's bend; a buoy should be attached to the anchor by a buoy line of 1-inch rope to mark its position, and to serve as a means of tripping it. One end of the buoy line is fastened to a ring of the buoy by a fisherman's bend, and the other round the crown of the anchor with a clove hitch split by the shank, and two half-hitches round the shank.

In the absence of anchors, or in a very rapid current, when the anchors are liable to drag or to pull the piers down by the head, a hawser (preferably wire rope) buoyed with floats can be stretched across the river (provided its width does not exceed 100 yards), and its ends secured to anchorages on each bank at a distance up-stream of about one-fourth the span; cables from the bridge piers are then secured to it. The danger of using this method under fire is that one shot may destroy the bridge.

5. **Passage of traffic.**—If a bridge has to remain down for some time, arrangements may have to be made for the passage of river traffic. This can be done by having two or more rafts, at the centre of the bridge, arranged for forming "cut"; or the two halves of the bridge may be swung, to afford the requisite passage.

6. Arrangements must always be made, up-stream, for the protection of a bridge from damage by floating substances, either by a boat patrol or by posting men at each pier to pole off such floating objects into the fairway. Down-stream, rafts with buoyed floating ropes should be anchored, to save men who fall off the bridge.

7. **Boat piers.**—Few boats, with the exception of heavy barges, are strong enough to allow of the baulks resting direct on their gunwales. A central transom should be improvised, by resting a beam on the thwarts, and blocking it up from underneath, so that the weight is brought directly on the kelson. (Plate **113**, Figs. 1 and 2).

In a non-tidal river, the boats should be placed "bow on" to the current and slightly down at the stern: in tidal rivers they must be placed pointing up and down-stream alternately.

Collapsible boats may sometimes be available. They should be used as described above, special care being taken that no weight comes on the gunwale. Their weight varies according to size and make. They are usually about 6 feet long and weigh about 200 lbs.

8. **Barrel piers.**—Piers of casks can be made up as shown in Plate **113**, Figs. 3, 4 and 5.

For a pier of seven 108-gallon casks the following are needed:—**Gunwales**, 21 feet by 4 inches by 5 inches; slings of 2½-inch rope, 6 fathoms long, with an eye splice 1 foot long at one end; braces of 1½-inch rope, 3 fathoms long, a small eye splice at one end, and a figure of 8 knot 1 foot 5 inches from the eye. For piers of 36-gallon casks, gunwales 9 feet by 4½ inches by 3 inches are required.

9. Large piers of small casks may be formed by first making piers of two to four casks (Plate **111**, Fig. 3); these are placed touching each other, and two baulks, which carry the road bearers, are secured to their gunwales.

A pier of two rows of casks may be made. Two braces for each cask are first fastened to a baulk, and stretched out perpendicularly to it; the casks are then placed end to end on each side of the baulk, and over their own braces. On the cask are laid two gunwales, previously lashed together at the ends, and at two intermediate points, by lashings which have afterwards to be racked up; the distance from out to out of the gunwales should be less than a bung diameter. The braces are then secured to the gunwales by two round turns and two half-hitches. The four lashings connecting the gunwales are then racked, the two at the ends are secured to the baulk by lashings, which are racked up, and, finally, the pair of braces on each cask are laced together as tightly as possible, so as to counteract the tendency of the braces to slip over the ends of the casks. This can readily be done by the spare end of one brace on each cask after it has been secured to the gunwale, figure of eight knots being previously made in each brace to prevent the lacing from slipping upwards.

10. When **log piers** are used, it is usually necessary to place the logs in two layers in order to give sufficient waterway between the piers; the logs are laid side by side, thick and thin ends alternating; they should then

be strongly secured with ropes or dogs, and, if possible, by cross and diagonal pieces of timber fastened by spikes; a central raised transom must be used. The up-stream end of the pier may, with advantage, be slightly convex. Such piers are most easily put together and manipulated in the water.

92. *Rafts.*

(*For buoyancy see Sec.* 94.)

1. When there is insufficient material for the construction of a bridge, or when it is only necessary to establish a ferry, rafts may be used, constructed of bridging equipment, of barrels, boats, logs, empty tins, planks or, as a very temporary measure, of waterproof material, such as tarpaulins or ground sheets, stuffed with straw, heather, ferns, &c. Cork floats are useful when the ferry may be subjected to heavy shell fire, but such floats are heavy to handle. Rafts may be towed, rowed, poled, hauled backwards and forwards across the gap by means of ropes, or, when there is a good current, utilized as "flying bridges" (*see* para. 8 below). Free rafts are generally most easily moved by towing; rafts with horses and vehicles cannot be rowed or poled, except under most favourable circumstances.

2. **Rafts** consist normally of two piers connected by baulks on which the decking is laid; the length of each pier must be twice the width of the platform of the raft. Three-pier rafts, when loaded, are unmanageable in a stream and are not recommended. When loading a raft with infantry, the men should sit down on the edge of the raft as close as possible, and then the central part of the raft should be loaded.

If the raft consists of one pier only (such rafts may be constructed of barrels or logs) the central quarter only of the platform should be loaded.

3. Rafts of two or more piers are merely sections of a floating bridge; for the construction of barrel, boat or log piers, *see* Sec. 91, 7 to 10; the decking is constructed in exactly the same way as a roadway; the lashings must be constantly watched.

4. **Log rafts** consist of one pier only; and are made in the same way as log piers in a bridge.

5. The **deck space** required for rafts may be estimated from the following dimensions:—

	Length.		Width.	
	ft.	ins.	ft.	ins.
Armed man, sitting	3	6	2	3
Horse, harnessed	8	0	4	0
18-pr. gun	14	6	6	3
18-pr. limber	5	9*	6	3
G.S. wagon	13	9*	6	1

6. When animals are carried, hand rails must be provided, and screens are always desirable, but may have to be dispensed with in a wind.

7. **Landing stages.**—Planks should be carried to enable men to get ashore from the raft; when animals and vehicles are carried, landing piers and landing

* Exclusive of pole.

gangways are necessary; landing piers are usually constructed of trestles, but in tidal waters, elaborate structures are necessary (Military Engineering, Vol. III), if the piers are to be available at all times. Landing gangways consist of five or six baulks lashed into a frame by cross baulks 2 feet from their ends. This frame forms a sliding span, sufficient decking being kept at each landing pier to complete the span. Plate **116** shows a type of lifting gangway, one end of which rests on a trestle, while the other can be adjusted by means of tackles to suit the height of the raft.

8. **Permanent ferries.**—In the simplest form of permanent ferry, boats or rafts are hauled backwards and forwards from bank to bank by means of ropes stretched across the river. Such a rope should, if attached to the boat, &c., be made fast at the stem or stern, not amidships. Where the current is rapid and regular, a flying bridge may be used. This is a form of bridge in which the action of the current is made to move a boat or raft across the stream by acting obliquely against its side, which should be kept at an angle of about 55° with the current (Plate **115**, Fig. 1). Long, narrow, deep boats with vertical sides are the best for the purpose, and straight reaches the most suitable places, as they are generally free from irregularities of current. A velocity of at least two miles an hour is required. It is necessary to have a vertical surface for the current to act against. If, therefore, the boat is a shallow one, or if the raft is made of casks or other material with a curved surface, vertical boards, called lee boards, must be lashed to its side. These lee boards consist of two or three planks held together by battens nailed to them. The depth of the lee board must be kept to a minimum, as the action of the current on the lee board causes the raft to tilt; a deep lee board may swamp the pier.

The cable, which should, if possible, float, can either be anchored in mid-stream or on shore at a bend of the river, and the raft can swing between two landing piers. The length of a swinging cable should be *from* one and a-half times to twice the breadth of the river, and it will work better if supported on intermediate buoys or floats to prevent it from dragging in the water. A number of telegraph wires, buoyed as above, make a good swinging cable.

Another way is to stretch a wire cable across the river, and arrange for the raft to travel along it by means of a block with a large sheave. If the cable is under water the sheave should be attached to a buoy to lift it clear of the mud.

A spare anchor and cable must always be carried on the raft.

9. **An extemporized raft** to carry an 18-pr. field gun without limber, or a weight not exceeding 24 cwts., may be constructed of four 18-foot by 15-foot tarpaulins stuffed with straw, as follows:—

Make a light framework of poles, 6 feet square by 2 feet 6 inches high, on the ground (a hole of similar dimensions will do almost as well). Then place two lashings about 24 feet long across the framework each way, and over these the tarpaulin, well soaked. Fill the tarpaulin with straw or similar material and trample it well down. The ends and sides of the tarpaulin are then folded over the straw, and the whole made into a compact bundle by securing the lashings across the top (Plate **117**, Figs. 1 and 2).

Two of these floats are then lashed together by means of two 14-foot spars. This forms half the raft. The other half is made in a similar manner. The two halves are then lashed to one another, 3 feet apart, by means of four 16-foot roadbearers. The raft will then measure 15 feet by 12 feet by 3 feet 6 inches. In such a raft the buoyancy is greatly in excess of that actually required to carry the load, but this is necessary owing to the kind of material employed and the short length of the piers. With good tarpaulins the buoyancy will remain good for at least eight hours.

The stores required are:—

Tarpaulins	4
Straw (tons)	$1\frac{1}{2}$
Planks	16
Spars (average 4 inches diameter), four 16 feet, four 14 feet, and two 12 feet	10
Lashings, 1-inch, about 3 fms. long	40
Do. $1\frac{1}{2}$-inch, about 6 fms. long...	16
Ropes, 2-inch, length according to width of river ...	2
Punting poles	2

10. Smaller rafts can be made in a similar manner by stuffing ground sheets with straw and placing them in a frame; 24 of these made into a raft will support a load of 1,800 pounds (Plate **117**, Figs. 3 and 4).

11. An extemporized boat made of a bivouac sheet stretched over timber framing is shown on Plate **118**.

93. *Fords.*

1. A ford, to be passable, should not exceed the following depths:—

For cavalry	4 feet.
For infantry	3 feet.
For tractors and light field artillery	2 feet 6 inches.
For lorries	2 feet.
For motor cars	1 foot 6 inches.
For caterpillars	4 feet.
For motor cyclists	1 foot.

2. The positions of fords are usually indicated on maps. They are often found just below weirs. The local inhabitant is the best source of information. A river which is not fordable straight across may sometimes be found passable between two bends as at A, B, Plate **115**, Fig. 2.

3. The approaches to a ford break down rapidly under continuous traffic, owing to the drip from men, horses and vehicles. They should be "corduroyed," the "pull out" side being done first, and ditched for 100 yards on either bank; the corduroy must be carried well into the water.

4. A ford with a sandy bottom is likely to become heavy. The bottom of a ford must be carefully examined before use, all holes being filled with stones or other hard material. Large stones and any obstacles to traffic must be removed.

5. For dry or fordable gaps, no provision is necessary for infantry, except in the case where the sides of the gap are precipitous, when provision must be made for ropes, knotted every 3 feet, with screw pickets to act as holdfasts, and ladders. Every endeavour should, however, be made to bridge a fordable stream on the immediate front of the attacking troops, in order to start the men dry.

6. A shallow (not exceeding 3 feet of water) muddy river may be made temporarily passable for infantry by laying mats made of canvas and wire netting on the top of the mud. A rope must be firmly fixed from bank to bank on either side of the mat.

7. **Marking fords.**—All fords must be clearly marked by strong pickets (4 inches and over), driven into the river bed above and below the ford; these pickets should project at least 2 feet above water level; their heads should be painted white, and should be connected by a strong rope securely anchored to holdfasts at each shore end. Four of the pickets in the deepest parts must be clearly marked in feet and inches so that the depth of the water may be easily seen.

8. Notice boards should be erected at each end of the ford, giving fordable depths for each arm.

94. *Buoyancy.*

1. **Bridges.**—When calculating the buoyancy required for a pier of a light floating bridge, the weight to be supported by any pier may be taken as the weight of the greatest load on one bay of the bridge plus the weight of one bay of superstructure. A pier which has sufficient buoyancy to carry infantry in fours will also carry light field artillery and first line transport. The maximum weight which can be brought on the bridge by infantry in fours is 5 cwts. for each foot run of bridge, and the weight of superstructure may be taken at 1½ cwts. for each foot run up to 15 feet span, so that the total weight will be 6½ cwts. for each foot run.

2. **Rafts.**—In the case of rafts, each pier must be capable of supporting the greatest load which may come on to it. On a raft designed to carry vehicles, the greatest load will be brought on a pier when the raft is being loaded or unloaded.

The superstructure will be the same as for a bridge and its weight must be allowed for.

The weight of an armed man may be taken as 200 lbs., and he occupies 8 square feet of deck space when sitting. A light draught horse weighs about 1,400 lbs. and requires 8 feet by 4 feet of deck space.

The loads brought on a raft by light artillery and G.S. wagons and the space occupied by them are given in the table on the next page.

3. The available buoyancy of a boat may be determined by loading it with unarmed men to within 12 inches of the gunwale and multiplying this number by 160; this gives the available buoyancy in pounds. In rough water or in a violent current a margin for safety must be allowed.

4. When using closed vessels such as casks, petrol tins, oil drums, &c., for floating piers, the safe buoyancy for bridging purposes must be taken at nine-tenths the actual buoyancy, so that the roadway will be clear of the water.

The actual buoyancy of a closed vessel is the weight of water it will displace when fully immersed, less its own weight. Thus, to find the actual buoyancy, the volume and weight of the vessel must be ascertained. In this connection, it is useful to note that a gallon of fresh water weighs 10 lbs. and that 1 cubic foot equals 6·25 gallons.

Maximum loads on rafts due to horse and light (horse-drawn) artillery and G.S. wagons.

Vehicle.	Weight in tons fully loaded.		Distance, axle to axle.	Overall width.	Overall height.	Wheel track.	Width of tyres.
	Front or limber wheels.	Rear or gun wheels.					
Equipments—			ft. in.	ft. in.	ft. in.	ft. in.	in.
Q.F. 13-pr., Mark I. carriage	·66	1·00	9 11½	6 3	4 8¾	5 3	3
Mark II. ammunition wagon and limber for above	·80	·85	7 3½	6 3	5 0	5 3	3
Q.F. 18-pr., Mark V. carriage* with Mark III. limber	·71	1·53	12 11	6 8	4 9½	5 6	3
Mark II. ammunition wagon and limber for above	·95	·95	7 4¾	6 3	5 2	5 3	3
Q.F. 4·5-in. howitzer, Mark I. carriage	·74	1·34	10 0½	6 3½	5 9	5 3	3
Mark I. ammunition wagon and limber for above	·80	1·22	8 7½	6 3½	4 11¼	5 3	3
Wagon, G.S.	1·35	1·00	7 1	6 4	6 11	5 3	2½

Vehicle.	Weight of gun and carriage with shield (less stores).	Overall length.	Overall width.		Overall height.	Wheel track.	Width of tyres.
			With shield.	Without shield.			
	Tons.	ft. in.	ft. in.	ft. in.			
Q.F. 3·7-in. howitzer, Mark I. carriage	·74	10 10	6 6	4 8¾	4 5½	4 0½	2

* Other marks do not exceed the dimensions stated.

PART III.—ACCOMMODATION

CHAPTER XIII

CAMPING ARRANGEMENTS

95. *Bivouacs, billets, and hutting.*

1. **Sites.**—The choice of sites for bivouacs, camps or hutments is determined by the tactical situation and the risk of disease.

The nearer the enemy the more important are the tactical considerations; the further the enemy, the more attention can be paid to the comfort and health of the men.

Under all circumstances strict attention to the sanitary conditions of men's accommodation has a direct bearing on the efficiency of the force.

2. The site for a camp or bivouac should be dry, on grass, and on a gentle slope. Steep slopes, woods with undergrowth, low lying meadows, the bottoms of valleys and newly-turned soil must be avoided. The water supply should, if possible, be within one mile.

3. **Bivouacs.**—Simple shelters may be formed in many ways. One method is to drive two forked sticks into the ground with a pole resting on them; branches are then laid resting on the pole, thick end uppermost at an angle of about 45°, and the screen made good with smaller branches, ferns, &c. A hurdle may be supported and treated in a similar way.

A shelter tent for four men may be formed with two blankets or waterproof sheets laced together at the ridge, the remaining two blankets being available for cover inside.

When materials are available, extemporized huts can be made by erecting a rough lean-to roof of light poles and brushwood rods, roughly thatched with branches, brushwood, pine brush, or covered with a tarpaulin (Plate 120).

4. Men sleeping on the ground in tents or bivouacs suffer discomfort from two main causes:—

i. Rain water.
ii. Draughts.

i. *Disposal of rain water.*

(*a*) See that the roof does not leak, and that joints between W.P. sheets, blankets, canvas, &c., are well overlapped.

(*b*) See that the water from the roof is conducted to the ground and that it cannot run back under the sides over the floor of the bivouac or tent. Plate 121 shows the right and wrong ways of disposing of rain water from tents and bivouacs. By the right method the water is conducted from the roof to the ground and is led away in the trench to the lowest ground. The earth from the trench protects the floor of the tent from any rush of water over the area of the camp caused by a sudden downpour. By the wrong method the rain running down the sides of the tent or bivouac soaks the earth which is placed on the canvas, and the water leaks through the canvas and over the floor.

ii. *Draughts.*—The proper arrangement for the disposal of water also prevents draughts along the level of the floor.

5. **Splinters.**—A method of protecting men sleeping in tents from splinters of shells and bombs is shown on Plate **122**, but it is open to the objection that the earth placed against the canvas walls of the tent will interfere with the efficient disposal of rain water as explained above.

6. **Billets.**—When villages are used as rest billets or training areas, the accommodation may be greatly increased by erecting bunks in barns and farm buildings.

The walls of barns may be repaired by using wattle and daub, *i.e.*, trimmed brushwood rods daubed over on both sides with clay in which is a proportion of any fibrous substance, such as straw, grass, &c., chopped into short lengths.

Roofs may be repaired with tarred felt on boarding, or with corrugated iron.

Bunks should be limited to two tiers, however much headroom there is: the bunking space required is 6 feet 6 inches by 2 feet for each man. The bed consists of grillage of hoop iron or plain wire: the mesh must not exceed 4 inches by 2½ inches, otherwise the occupants can insert the heels of their boots between the wires and the bunks are rapidly damaged. Rabbit wire netting, covered with canvas, may be used, but sags badly under a load and does not last long.

Windows of oiled canvas should be provided; these add to cleanliness and comfort.

7. **Hutting.**—When hutted camps are necessary, the design of the huts depends upon the theatre of war. This subject is dealt with in Military Engineering, Vol. VII.

If huts are constructed of material drawn from the engineer parks, the most convenient form is rectangular in plan, 17 or 18 feet wide, to allow of bunks on either side. When attack by aeroplanes is expected only one tier of bunks can be provided, and that must be as close to the ground as possible. The floor should be of hard material or wood, the sides and roof of corrugated iron or of wood covered with tarred paper or felt, and the windows of oiled canvas or glass.

Comfortable huts can also be made of locally obtained materials secured to a framework of rough timber. Such materials include matting, brushwood, reeds, &c.

A useful type of hut consists of a thatched roof supported on uprights and walls of "Malay Mat" made with brushwood and wire plastered with mud. For warm climates, ample space for ventilation should be left at the top of the walls.

Splinter-proof walls of earth, shingle, &c., must be constructed round each hut as a protection against splinters from shells or bombs from aeroplanes. To economize material and labour and to increase the protection afforded, the floors of all huts should be close to ground level, or in dry sites below; on sloping ground the site of each hut should be levelled by cutting into the slope of the hill.

8. **Stoves.**—If stoves are provided, the floors, walls, and roofs of huts and billets must be specially protected with sheet iron or tin where the stoves stand, or the stove piping passes through.

9. **Stables** must be sited near to an existing road; Plate **123** shows a typical site plan. A properly made approach road (Chapter XV) is necessary, and to save labour and materials this should be as short as possible. The section on Plate **123** shows a type of shelter which affords accommodation for two rows of horses; the central passage includes the road and serves as a harness room, until a separate shed can be provided. Stables can also be constructed with walls of "wattle and daub" or matting supported on wire netting, roofed with thatch or canvas. The sides and ends must give protection from wind, and the roof should be weather proof.

Standings must be made of the hardest material obtainable, e.g., concrete, brick or corduroy of logs, and they must be well drained. Stables are particularly vulnerable to attack from aeroplanes using bombs. Earth or mud walls should be built at the sides and ends to stop splinters and in long stables traverses must divide the stable into compartments holding not more than 20 horses (Plate **123**).

96. *Water supply.*

(*See* Military Engineering, Vol. VI, and Manual of Military Hygiene.)

1. **The quantity of water** required daily is as follows :—

In bivouacs (absolute minimum) :

1 gallon for each man.
3 gallons for each animal.

In temporary camps :

5 gallons for each man.
10 gallons for each horse.

In standing camps, rest billets, &c. :

15 gallons for each man.
10 gallons for each animal.

Hot weather and hard work will nearly double ordinary requirements, and, in making any calculation of the amount required, these factors must be considered.

2. **The sources of supply** usually available are streams, ponds and wells.

Small ponds and shallow wells should be avoided for drinking purposes. **Water in shell-holes must never be used for drinking, as it may be poisoned.**

3. **The rough average yield of a stream** may be measured as follows :—

Select some 15 yards of the stream where the channel is fairly uniform and there are no eddies. Take the breadth and average depth in feet in three or four places. Drop in a chip of wood and find the time it takes to travel, say, 30 feet. Thus obtain the surface velocity in feet per second. Four-fifths of this will give the mean velocity, and this multiplied by the average sectional area in square feet will give the yield per second in cubic feet of water (one cubic foot equals six and a quarter gallons). Sec. 22, Military Engineering, Vol. VI, 1922, deals with the more accurate methods of gauging the supply of streams.

The yield from a well may be gauged by pumping to lower the level one foot, and then, noting how long it takes to fill to the original level. Where there is no risk of shortage of water, a more reliable measurement may be obtained by pumping the well almost dry and noting the time taken to fill to the original level. The contents of circular wells per foot deep is as follows :— 3 feet diameter, 44 gallons ; 4 feet diameter, 78 gallons ; 5 feet diameter, 122 gallons ; 6 feet diameter, 176 gallons.

Water can be obtained, if necessary, from a marsh, water courses or holes by the methods shown on Plate **124**.

4. **Quality of water.**—The source of supply must be carefully investigated, and measures taken to prevent the pollution of the water *en route* to the drinking supply. Wells must be tested at the earliest opportunity, and each well clearly marked as fit for drinking or for washing purposes only.

5. **Methods of purifying water.**—On active service all water must be considered as polluted. Water may be purified :—

i. *By the addition of chemicals.*

(*a*) *Clarification by alum* and subsequent sterilization by chlorine.—This is the standard method adopted in the army, and it is employed in a variety of ways depending upon local and other conditions.

(A). *Preliminary clarification by clarifying powder.* (Aluminium sulphate, 2 parts, anhydrous sodium carbonate, 1 part) :—

(1) Addition of clarifying powder (five grains per gallon), resulting in the formation of aluminium hydroxide, a white gelatinous substance which slowly sediments, or can be removed by filtration through sand or fabric.

This hydroxide in sedimentation carries with it suspended matters and over 90 per cent. of the organisms in the water. Similarly the layer of hydroxide on the sand or fabric retains and prevents the passage of suspended matters and the same percentage of germs originally in the water.

(2) Removal of aluminium hydroxide by :—(*a*) Sedimentation (as in certain land plants and barges); (*b*) filtration through sand (as in the water sterilizing lorry); (*c*) filtration through fabric (as in the regimental water cart); (*d*) combination of (*a*), (*b*) and (*c*).

(B). *Subsequent sterilization by chlorine* :—

(1) Addition of one part per million free chlorine (allowing for "deviation") in the form of : (*a*) water sterilizing powder (chlorine) ; (*b*) gaseous chlorine.

The water sterilizing powder (chlorine) consists of an intimate mixture by weight of 80 per cent. commercial bleaching powder and 20 per cent. of freshly ignited quicklime (calcium oxide). The powder when fresh must contain by weight not less than 25 per cent. of available chlorine and not less than 7½ per cent. of uncombined quicklime.

(2) Contact for thirty minutes.

(3) Dechlorination as required by : (*a*) sulphur dixoide ; (*b*) sodium thiosulphate ("hypo") ; or (*c*) sodium sulphite.

(*b*) *Bisulphate of soda.*—Two tablets (each 15 grs.) of bisulphate of soda, flavoured with saccharine and oil of lemon, dissolved in the full contents of a water bottle and allowed to stand for twenty minutes, gives an acid solution with a flavour resembling lemonade. This is the present army method of individual water sterilization. It has many disadvantages, the chief of which are as follows:—The solution is metal-solvent and produces an objectionable taste on prolonged contact with an aluminium water-bottle. Its use is inadvisable in copper water-bottles, but it can be safely used in bottles made of enamelled iron, so long as the enamel remains intact. If the enamel is chipped, the exposed iron rapidly corrodes and ferrous sulphate is formed, giving an objectionable taste and colour to the water.

If exposed to the atmosphere these tablets take up moisture, and sufficient sulphuric acid is liberated to burn clothing and skin.

(*c*) *General.*—A number of other chemicals have been used from time to time, but all have their limitations and disadvantages for use in the army. In an emergency, however, it is well to remember that tincture of iodine (six drops to the contents of a water-bottle) is better than nothing and can always be obtained from a field medical unit.

ii. *By heat.*

(*a*) *Boiling.*—This method of sterilization, if carefully carried out by boiling the water for five minutes and then protecting it from recontamination, is efficient, but it yields an unpalatable water, and the method is rarely practicable for considerable bodies of troops owing to the slowness of the procedure, and difficulties in the provision and transport of fuel, and in cooling the water. Should this method be employed the water is best consumed in the form of tea. If the water contains obvious suspended matter, it should be clarified before it is boiled by (*a*) using the clarifying powder; (*b*) filtration; or (*c*) a combination of (*a*) and (*b*).

(*b*) *Heat-exchange.*—Different forms of heat-exchange apparatus have been devised, the principle in each being the separation of the incoming cold water from the out-going hot water by a thin metal diaphragm, with a resultant cooling of the sterilized hot water to a drinkable temperature, and a corresponding rise in the temperature of the incoming cold water, and an economy in fuel.

iii. *By filtration.*

Filtration through sand and gravel does not render a polluted water safe to drink, but it is commonly employed, either alone or in combination with alum precipitation, for the purpose of clarifying water as a preliminary to other methods of sterilization.

For individual sterilization the Berkfeld and Pasteur-Chamberland filter candles, which are hollow bougies of specially prepared porcelain contained in a metal case and screwed to a water tap, may be of use if no safer method is available. Their delivery is slow, and if they are to keep back disease germs the porcelain must be absolutely sound, union between the filter and the delivery pipe must be perfect, and they must be scrubbed and cleansed in boiling water every three days. Both are unsuitable for turbid water.

iv. *Special purification processes.*

(*a*) *Removal of poisons.*—A special test case was introduced during the Great War for the rapid detection of certain poisons (arsenic, antimony, mercury, lead, copper and cyanides) in water in the field. The method of removal of these poisons from water is to convert them into insoluble forms by means of appropriate reagents and then remove the precipitate by filtration through sand.

(*b*) *Saline water.*—Distillation is the only suitable method by which sea or brackish water can be rendered fit for consumption. Fixed, mobile and improvised distillation plants were used in Egypt, Gallipoli, &c., during the Great War.

(*c*) *Removal of sand.*—In Egypt and other countries the presence of very fine sand in water, especially from bore holes, interferes with purification by delaying sedimentation. Fine wire gauze or the Ashford sand strainer may be used to free the water from the sand. (*See* Military Engineering, Vol. VI, Sec. **39**, 2).

(*d*) *Schistosomata.*—In Egypt and certain parts of Africa special measures may be required to free the water from these parasites. Where risk of contamination by these parasites exists cresoled water (1 in 10,000) may be used for washing; drinking water intakes should be screened with wire gauze (sixteen holes to the inch) to exclude the snail hosts of the parasites, and drinking water may be either specially chlorinated (two parts per million) and subsequently dechlorinated, or stored for forty-eight hours after ordinary chlorination.

(*e*) *Leeches.*—Small leeches are prevalent in many water sources in tropical and sub-tropical areas. They are excluded by straining the water through wire gauze twenty holes to the inch.

(*f*) *Mosquitoes.*—Mosquito breeding in water supplies may be prevented by screening with wire gauze, eighteen holes to the inch; the addition of cresol—a concentration of 1–80,000 destroys the mosquito larvæ, and is scarcely detectable by taste. Oiling the water surface—another recognized method—is not suitable for use in drinking water supplies.

6. The lay out of a simple improvised alum-chlorine purification plant is shown in Plate **126**, in which an elevated supply tank is connected to a water cart point of the usual type. (*See* Sec. **83**, 6, Military Engineering, Vol. VI, 1922).

7. **Raising water.**—The pump in general use in the service is the "lift and force" pump, weighing 84 lbs. complete. It is worked by two men. When in good order it can lift water from a maximum depth of 28 feet and force it 32 feet (*i.e.*, 60 feet in all, at a rate of 12 gallons a minute). Four are carried in the field by each field squadron, and four by each field company of engineers and by each field park company. To obtain the best results the height of lift or suction should be reduced to a minimum, and can rarely exceed 20 feet. The end of the suction pipe must never be allowed to rest on the silt or mud at the bottom of a well or stream.

From deep wells, unless power driven pumps are available, water must be raised by buckets and ropes, windlasses being improvised as soon as possible. Another alternative is to use a water bag, which is lowered into a well by ropes and drawn up by animal power. Depths of 180 feet can be reached, and the bucket can raise 15 gallons at a time. (Plate **125**).

8. **Control of water supply.**—Where water is limited troops must be notified and the utmost care taken to conserve the supply. Immediately on the arrival of the troops (before if possible) the available sources of supply must be distributed under the following headings:—

i. Watering places for men (white flags).
ii. Watering places for animals (blue flags).
iii. Places where water for washing purposes may be drawn (red flags).

In a stream men should draw drinking water above the place for animals, while water for washing, &c., must be drawn below it.

Every precaution must be taken not to foul the stream: there may be other troops down-stream. Sentries or patrols must be established to see that the sources of supply are used as detailed.

9. **Watering arrangements for men.**

i. Cooking utensils must not be dipped in ponds or streams: they must be filled by dippers.
ii. Arrangements must be made as soon as possible to enable water carts to be filled quickly by installing storage tanks with hose deliveries.
iii. Special provision for filling water-bottles and petrol tins is most useful.

At all water cart filling points, besides the hose required for the carts, a water-bottle filler should be provided. This is a 2-inch iron pipe, fitted at intervals with ⅜-inch bibcocks to which nozzles small enough to fit into water-bottles are fitted. If funnels are provided they should be made so as to allow air to escape from the bottle or tin.

10. **Watering arrangements for animals.**

i. Animals must not enter streams or ponds; watering must be by bucket or from a system of trenches as shown on Plate 124, Fig. 2, the source of supply being fenced off.
ii. As soon as possible pumps and troughs must be installed: there should be sufficient troughing to enable all animals to be watered in one hour; an animal should be allowed five minutes to drink and four feet of lateral space.

   Troughs may be of sheet or corrugated iron or wood, either lined with canvas or caulked; canvas troughs do not last long: if used, they must be slightly raised off the ground and it is essential to protect them from damage by a stout guard rail all round, one foot higher than and one foot clear of the troughs.

   Troughs must be placed, if possible, so that horses proceeding to and from water shall not use roads required for general traffic. They must never be placed at the side of a traffic road.
iii. Watering places should be surrounded by stout barricades with narrow IN and OUT openings to regulate traffic.
iv. The ground at watering places cuts up rapidly; corduroy or brick standings should be laid for a width of 10 feet on either side of the troughs.
v. A special railed-in trough must be provided for animals under suspicion of infectious disease, and marked with conspicuous notice boards.

vi. In cases where water has to be rationed strictly, only a limited quantity should be pumped into the troughs at a time. When the trough is emptied by one batch of horses, they should be led away, and the trough filled just sufficiently for the next batch of horses to be watered. Horses that have not been watered for 24 hours or possibly longer always make a rush at a trough and will not leave it so long as a drop of water remains.

11. **Washing arrangements.**—No washing should be allowed within 30 yards of the water supply: empty biscuit tins, &c., should be used to draw water for this purpose; ablution benches (Plate **127**) should be made as soon as possible and drains provided. (18 feet run for each 100 men).

12. **Miscellaneous.**—All watering points must be carefully drained.

Grease traps.—Waste water from ablution benches, kitchens, &c. must be cleared of grease before being discharged into soak pits.

Designs of grease traps for this purpose are shown on Plate **128**.

Surface water must be prevented from running into wells by brick or concrete copings.

Direction boards to the watering places must be provided liberally.

13. The subject of water supply is dealt with in detail in Military Engineering Vol. VI.

97. *Cooking arrangements.*

1. **In the open.**—The simplest arrangement for cooking in the field for any party over 20, if the halts are not of long duration, is to place a proportion of the kettles on the ground in two parallel rows about 9 inches apart, handles outwards, block the leeward end of the trench so formed with another kettle, lay the fire between the kettles and place one or two rows of kettles on those already in position.

Mess tins can be arranged similarly, but in their case not more than eight should be used together.

2. **Trenches.**—The most economical method when time is available, is to dig or raise a narrow sloping trench for the fire on which the kettles are placed. The interstices are then filled up with clay so that the fire, fed from the windward end, may draw right through. A chimney may be built at the other end to increase the draught.

3. Types of ovens and cookers are given (Plates **129** to **134**) Those shown on Plates **129** to **133** are best built in brick, but with care can be built with sods, if good sods are obtainable, or with biscuit tins.

The "Camel Back" type of field kitchen, Plate **132**, is suitable for officers' and serjeants' messes, or for about 50 men; it can be built with bricks, sods, or tins filled with earth, but all joints must be made as air-tight as possible.

Three pieces of sheet or corrugated iron are required:—

One for the oven sides, top and bottom made to the shape required.
One for the oven jacket shown on Plate **132**.
One for the oven door.

Sheet iron is best if available; piping of any kind can be used for the chimney.

The type shown on Plate **134** being portable, is suitable for small detached parties.

4. Weatherproof cover should be provided for cooks to enable them to prepare food properly and to provide for the storage of rations. A simple timber framework with end, sides and roof of corrugated iron will suffice. The roof should have a good fall.

5. For storing rations a fly-proof safe is essential in warm weather. A safe of light timber framing provided with hooks from which to hang meat and covered with fly-proof gauze can be made to any size required. A portable pattern is shown on Plate **135**.

98. *Latrines.*

(*See* Manual of Military Hygiene.)

1. **Sites** for latrines must be very carefully selected. They should be situated as far as possible from the water supply and kitchens, and when practicable on another side of the camp and to leeward of kitchens. Flies are greatly responsible for spreading infection. No filtration must reach the water supply.

2. Latrines and urine pits must be dug immediately on arrival of troops in their bivouac or camp. These should be replaced as soon as possible by urinals of the type shown on Plate **136**, and by deep trench latrines (Plate **137**). Where deep trench latrines are impracticable, bucket latrines should be provided (Plate **138**). For use at night three-trough pattern urinals as depicted on Plate **136**, but of half the length, should be erected as follows:—One near the Institutes, and one in a central position on either flank of the men's tents or bivouacs. These should be illuminated by means of a lantern on a post and marked " For night use only."

3. **Accommodation.**—Shallow trenches should be provided at the rate of five trenches for each 100 men. Five yards run of deep trench is required for each 100 men. Seating accommodation should be provided, if possible, for 5 per cent. of the men.

4. **Screens** of canvas or bushes and weather-proof overhead cover should be provided, and latrines must be clearly marked "Officers," "W.Os. and N.C.Os.," "Men," or "Natives."

99. *Refuse.*

1. **Camp refuse** must be collected in fly-proof receptacles and burned, the residue being buried. If this is properly done there need be no fly nuisance, even in Eastern countries.

A type of temporary incinerator is shown on Plate **139**. An oil drum with the bottom knocked out, supported on a grid of iron bars resting on bricks or stones, is equally good. Spaces must be left below the grid to form air holes and for raking out ashes. A more permanent type of destructor may be built in brick (*see* Sec. **72**, and Appendix 1, Manual of Military Hygiene, 1921).

In camps and trench systems numerous small receptacles (sandbags, X.P.M. gabions, &c.) must be provided for paper, cigarette tins, &c.

2. Disposal of manure.—Whenever possible, manure should be burnt on incinerators about 6 feet square made of expanded metal or bands from bales of compressed forage, or any similar material raised a foot or so off the ground; various types of incinerators will be found illustrated in the Manual of Military Hygiene. If it cannot be burnt, definite places must be allocated where manure may be dumped; these should be at a considerable distance from camps and horse lines; the heaps must be properly built up, and covered with 1 foot of earth.

3. Disposal of dead animals.—If incinerators for burning dead animals have not been constructed, the animals must be skinned, cut open, and buried, the place being clearly marked as "foul ground."

CHAPTER XIV

SHELTERS AND DUG-OUTS

100. *Degrees of protection.*

1. **Shelters** for the protection of troops, armament and ammunition against the effect of enemy projectiles are provided, either in specially constructed buildings on the surface, or in underground chambers and passages called dug-outs.

2. **Protection** is given in three degrees :—

- i. **Shrapnel-proof.**—This will keep out the weather, shrapnel, indirect M.G. fire, and small splinters.
- ii. **Shell-proof.**—To keep out all shell from guns, howitzers, and mortars up to 6 inch.
- iii. **Bomb-proof.**—To keep out aeroplane bombs with delay action fuzes, and all shell from guns, howitzers and mortars.

The construction of shell-proof and bomb-proof buildings above ground involves a large amount of steel, concrete, and highly skilled labour; this subject is dealt with in Military Engineering, Vol. II.

101. *Types of shelters.*

1. To assist in the construction of protected accommodation, both above ground and under ground, the following special materials are provided (Appendix VII, Tables 5 and 6).

- i. Small corrugated steel shelters.
- ii. Large corrugated steel shelters.
- iii. Curved corrugated-iron sheets.
- iv. Troughing plates in 6- and 9-foot lengths.
- v. Timber, rails, steel joists, logs, &c.

2. **The small corrugated steel shelter** (Plate **140**).—The complete shelter consists of five segments or arches, each composed of two sheets, 2 feet 9 inches in width, which overlap 12 inches, and are fastened together by six half-inch bolts, 1½ inches long, through holes drilled in the sheets for this purpose; each segment overlaps the next by half a corrugation (3 inches).

To erect, lay out the 4-inch by 3-inch timber bearers, put the curved segments into position, drive in the clasp nails provided, and nail on the 2-inch fillet.

Five segments of a small corrugated steel shelter make a shelter 12 feet 9 inches long, as shown in perspective on Plate **140**. If more head room is required than 3 feet 8 inches, it can be raised on timber frames (Plate **141**, Fig. 1); it should not be supported on a sandbag wall.

3. **The large corrugated steel shelter** consists of seven segments or arches, each composed of three sheets of corrugated steel 2 feet 9 inches wide, which overlap 18 inches, and are fastened together and erected in the same way as a small corrugated steel shelter.

An example of the use of a large corrugated steel shelter is given on Plate **142.**

The sheets of steel shelters may be used singly, in which case wall plates must be provided. Single sheets should not be used to support big weights.

4. **Curved corrugated iron** can be used resting on trench boards on edge. This makes a quickly constructed trench shelter, as shown on Plate **143.** They can also be used on timber frames, as shown on Plate **141,** Figs. 2 and 3.

5. **Troughing plates,** 6 feet or 9 feet long and 3 feet 3 inches wide, are considerably stronger than curved corrugated iron.

A centre support is required.

102. *General instructions.*

1. Before commencing any shelter or dug-out, decide what degree of protection is to be provided, and what number of men are to be accommodated.

2. Dug-outs, intended to be shrapnel-proof and shell-proof, are made on the "cut and cover" principle, that is to say, an excavation is made in which a shelter is built, and then covered up.

When corrugated steel shelters are used for this purpose, the end not used as an entrance must be closed and firmly strutted. The framework on which the shelter rests must be braced to prevent collapse, and, in the case of the large steel shelter, the arch must be supported centrally throughout its length.

Accommodation required in buildings which are exposed to the fire of field guns can be made proof against splinters and light shells by using the rearward ground floor rooms. A sandbag wall is built inside the rooms, and a strutted roof provided to support any falling debris; or a large steel shelter can be erected inside the rooms. This should be placed well back from the walls and covered with sandbags or concrete. The interval between the shelter and wall should not be filled in with loose earth or rubble, as these materials will only serve to transmit the shock of a bursting shell.

3. All shelters and dug-outs must be constructed to resist the effect of the explosion of a shell near them and consequent collapse, even if they are not designed to resist a direct hit.

The framework must, therefore, be in the form of a box braced in every direction. The essential points in construction are:—

i. Sides must be prevented from collapsing inwards, by being strutted top and bottom. When square timber is used, the heads and feet should be kept apart by a spreader nailed on; cleats are useless (Plate **144,** Fig. 3). Notches must not be used.

ii. The whole box must be prevented from distortion by diagonal bracing on sides and ends.

iii. Except in hard chalk or rock, sills or bearing plates must be placed under the uprights supporting the roof.

iv. Joists must be laid on edge to obtain the full strength (Plate **146**).
v. They must be placed so that the spans are as short as possible.
vi. Timber joists having large knots should be placed so that the knots are in the upper and not in the lower surface (Plate **144**, Fig. 1).
vii. The ends of timber joists must have a good bearing on reliable supports (Plates **144**, Figs. 2 and 4, and **145**).
viii. Uprights should be round or as nearly square as possible.
ix. When fastening heavy timbers together, dogs and spikes must not be driven within 3 inches of the edge or 4 inches of the end of the timbers; dogs must be placed on both sides of the frame. Auger holes must be bored for spikes or the latter will split the timbers.

103. *Roofs.*

1. The roof must be weatherproof. Corrugated iron or similar material, used for this purpose, must be graded to throw off water, and this and other surface water must be prevented from entering the shelter or dug-out.

The grading of the roof is done by having one side or end slightly higher than the other.

When laying corrugated iron on a slope, the lower layers are laid first, the upper layers overlapping the lower ones. Nails should be driven through the ridges, not through the valleys of corrugated iron.

2. Where two girders cross each other they must be firmly clamped together to prevent lateral movement; distance pieces must be fitted betweeen parallel girders.

3. Table 6, Appendix VIII, gives the safe load which can be carried by certain girders and rails. For timber joists and round poles Table 5 can be used thus—to find the safe load for each joist or pole for any span of roof divide 16,000 lbs. by the number given in Table 5 for the joist or pole at the required span. Example: 9-inch by 3-inch joists will safely carry $\frac{16,000}{5}$ lbs. a joist in a roof of 7-foot span, 5 being the figure given in Table 5 for 9-inch by 3-inch joists over a span of 7 feet.

4. To find the weight of earth in lbs. which may be supported by one girder or joist, multiply the span in feet by the distance apart of the girders in feet by the depth of earth in feet by 100 (a cubic foot of earth weighs roughly 100 lbs.).

Thus, to support a roof of 2 feet 6 inches of earth, if the span is 8 feet, 40-lb. rails may be used, spaced 2 feet apart, or 5-inch by 3-inch girders 3 feet apart (Table 6).

104. *Shrapnel-proofs.*

1. Shrapnel-proof protection is given by 12 inches to 2 feet 6 inches of earth. Earth is not shell-proof until some 20 to 30 feet are used, and anything more than 2 feet 6 inches only increases the explosive force of the shell. A bursting course of broken bricks, stones, &c., is always a useful addition to shrapnel-proof cover, but the depth of the whole roof covering should not exceed 2 feet 6 inches.

2. The earth and bursting course is usually supported on one of the shelters described in Sec. **101** and illustrated in Plate **143**, but a revetted trench can be roofed with corrugated iron sheets, hurdles, planks, &c.,

supported by joists, poles, &c., laid across the trench. Fire and communication trenches must not be treated in this way as they quickly become blocked under shell fire, but recesses should be dug off them preferably behind a traverse as shown on Plate 143; slit trenches (Sec. 53, 2) provide good shrapnel-proof protection. Protection of huts and tents from splinters is dealt with under those headings in Chapter XIII, but in large camps this protection should be supplemented by slit trenches.

105. *Shell-proofs.*

1. The cover required to give full protection from shells up to 6-inch is as follows (Plate 147).

   i. Burster. This turns the nose of the shell and causes it to burst before it has penetrated too far.
   ii. A cushion to absorb shock.
   iii. Distributing course. This spreads the stresses caused by the explosion over a large area of the roof.
   iv. A second cushion. This acts as a buffer between the distributing course and the roof.
   v. A thin layer of hard material immediately above the roof, to stop splinters.

2. A burster of non-rigid material—broken bricks, stone sets, or hard chalk—about 2 feet thick, has been found superior to slabs, rails, concrete, &c., for, although it must be thicker, it is less susceptible to permanent damage by shell, and is more easily replaced and repaired.

The burster must be carried well over the front and sides, so as to protect them as well as the roof.

3. The cushion should be made of the spoil obtained from the excavation of the dug-out. It should be about 3 feet thick.

4. The distributing course should consist of logs, rails, &c., tied together with stout wire, so as to form a mat. The material should be laid touching and, if possible, in two layers.

5. The second cushion may be similar to the first.

6. The inner layer may consist of 6 inches of bricks, stone or concrete laid on boards or corrugated iron.

7. Plate 147 shows some details of construction for a dug-out proof against a 6-inch shell. The timber construction can be dispensed with by using one of the steel shelters described in Sec. 101.

8. **Cellars.**—Full use should be made of cellars for providing protected accommodation. Whether this is to be splinter-proof or shell-proof, the first essential is to shore up the roof with stout pit-props or frames sufficiently strong to support any protective layer which may be added, as well as the weight of any debris which may be dislodged from the upper storeys.

All cellars must be provided with two entrances, protected with gas curtains.

Splinter-proof protection. Roofs of brick or concrete will usually be splinter-proof in themselves, but the ordinary timber joist and boarded roof will require the addition of a protective layer as described in Sec. 104.

Shell-proof protection. In well-built houses, existing walls or roofs act as bursters, and as these are knocked down the covering of the cellar is automatically increased. It is, however, safest to provide shell-proof protection from the first. This may take the form of three feet of reinforced concrete, or protection as shown in Plate 147.

106. *Tunnelled dug-outs.*

1. Provided that the ground is suitable and that the site is nor too close to the enemy, tunnelled dug-outs are the most satisfactory type of shell-proof accommodation on any scale. They have the following advantages over concrete or cut-and-cover dug-outs :—

i. Their construction involves less labour in proportion to the accommodation given and affords more immediate results.
ii. They can be constructed by unskilled labour with very little supervision.
iii. They give protection against penetration and concussion effect.
iv. They can be more easily concealed.

2. Complete protection against shells of large calibre (8-inch and over) can seldom be gained without descending to impracticable depths. Generally speaking, all underground work should be provided with sufficient head cover to exclude 6-inch howitzer and mortar shell fitted with delay action fuze.

The thickness of cover required under these circumstances will be, respectively, as follows :—

Made earth	35 feet.	
Clay	30 ,,	
Gravel	25 ,,	
Chalk	25 ,,	to 20 feet.
Hard rock	15 ,,	

In chalk, economy in timber may often be effected by sinking slightly deeper than necessary for cover to reach hard sound chalk in which it is not necessary to timber galleries and chambers.

3. **Disposal of spoil and camouflage.**—Concealment of the spoil excavated is of the utmost importance (Appendix X), and the total amount to be disposed of must be considered before work is begun.

4. **Material.**—The material generally available for lining galleries and chambers is :—

For inclines and galleries :—

9-inch by 3-inch timber setts, uprights 6 feet 6 inches long, cross-pieces 3 feet 3 inches long, spreaders 9 inches by 1 inch and 2 feet 9 inches long (Plate 148, Fig. 1).

9-inch by 3-inch timber setts, uprights 5 feet long, cross-pieces 3 feet 3 inches long, spreaders 2 feet 9 inches long (Plate 148, Fig. 2).

For chambers :—

Pit props, 4½ to 6 inches in diameter. Steel girders (R.S. joists), 5 inches by 3 inches and 9 feet long.

Lagging (1½ to 2-inch boarding), in various lengths.

5. The **accommodation** which may have to be provided includes the following :—

- i. Command headquarters for company, battalion and higher fighting formations (Plates **149, 150,** and **151**).
- ii. Accommodation for machine-gun personnel (Plate **152**).
- iii. Accommodation for personnel working in observation posts.
- iv. Living dug-outs for infantry and artillery.
- v. Subways.
- vi. Dressing stations (Plate **153**).

6. **Design.**—Two main types of dug-outs are given, viz. :—

Type "A" (Plate **154**, Fig. 1), which is more suitable for offices and officers' quarters.

Type "B" (Plate **154**, Fig. 2), which is more suitable for men's quarters. This type involves less excavation for the accommodation provided and gives better ventilation.

7. **Entrances** (Plate **155**).—Every dug-out must have at least two entrances not less than 40 feet apart.

No attempt should be made to strengthen the head of an incline. No practical means will make it proof against a direct hit, and the use of concrete and girders only render clearing and repair more difficult.

It is essential to prevent entrances becoming sumps for the drainage of the trench. For this reason they should never start from the bottom of the trench. Flooding is best prevented by commencing the incline at the end of a short return of such a length as to allow 5 feet between the side of the trench and the step at trench board level (Plate **155**, Fig. 1). This space allows of extra steps being added as necessary, without blocking the entrance. The return should be made weather-proof (not shrapnel-proof) and camouflaged.

8. **Inclines.**—Inclines should be driven at a slope of 45° and should be close timbered with setts 3 inches thick for at least 15 feet; open timbering can then be used if soil is suitable. The minimum width admissible is 2 feet 9 inches, as in the standard sett. There are two methods of timbering, viz., vertical and normal.

Vertical timbering (Plate **155**, Fig. 1) is not recommended for unskilled men, as they have difficulty in cutting the steps properly, with the result that they crumble and the frames slip under the shock of a shell. Legs shorter than 6 feet give insufficient headroom. Steps should have 9 inches tread and 9 inches rise. Steps narrower than 8 inches are dangerous and should not be used. Vertical timbering is safer when rising through bad ground.

Normal timbering (Plate **155**, Fig. 2) is stronger, requires legs of shorter length to give the necessary headroom, and irregularity in the width of the setts used does not affect the stairway as steps are put in afterwards.

9. **Excavation and timbering.**—For either type first excavate the bottom and place the ground sill truly. Then put in the legs, excavating only enough ground to place them. Then excavate for and place the top sill. Dig out the remaining ground.

Never attempt to excavate for several setts to be timbered later; this endangers the lives of those working, and, if the face or sides begin to "run," involves an immense amount of labour and leaves a weak entrance.

Each sett should be "laced" back to the previous one, immediately it is put in, at top and bottom, by means of a short length of wood about 1 foot 6 inches by 4 inches by 1 inch nailed to both setts. In the case of an incline timbered normal to the slope, the side pieces of the steps form the bottom lacing.

Afterwards all setts should be strung together with 4-inch by 1-inch wooden runners, spiked about 6 inches from the top and bottom of each side or flat bar iron specially slotted.

Solid chalk is most easily broken to a "cut" (*i.e.*, a narrow excavation, usually down one side). If timber is put in as above there is a cut, top, bottom and both sides. Picks should be systematically worked to break to one or other of these cuts and not used indiscriminately over the face.

For normal timbering a templet in the shape of a 45 degrees triangle with 2-foot sides and a plummet should be provided.

Tool recesses should be provided at the bottom of each incline.

10. **Galleries.**—In bad and doubtful ground, galleries should be close timbered, but in ordinary chalk and dry clay the setts may be spaced up to a maximum of 4 feet, thus economizing timber. Top lagging ($1\frac{1}{2}$ to 2-inch boarding) must always be used and, except in solid chalk, side lagging of 1 to $1\frac{1}{2}$-inch boarding, corrugated iron or expanded metal, &c., is also necessary.

When there is any doubt as to the stability of the roof, work should be carried out by "spiling" (*i.e.*, supporting the roof ahead of the excavation). In loose, heavy ground this is the only method to adopt.

Plate **156** illustrates spiling. The whaling board, of 4-inch by 2-inch timber, rests on distance pieces placed on top of the top sill of the ordinary frame. The distance pieces are large enough to allow the spiling boards (*i.e.*, overhead lagging) to be hammered forward between the whaling board and top sill.

The spiling boards are maintained at the original angle by using a spare top sill as a distance piece, bearing on the spiling boards of the sett behind.

In very heavy ground the spiling boards may bend with the weight before they can be driven home; in this case intermediate temporary setts are used. The forward sett supports the end of spiling boards, while the back one serves as a distance piece to maintain the angle of drive. The boards are driven from underneath the cap. This method necessitates the excavation of the ground between setts in two distinct operations; first, to place the intermediate sett and then to place the permanent sett. If it is necessary to pick out the ground ahead of the spiling boards to facilitate driving, only pick out enough to allow one board to be driven at a time.

Spiling boards should be at least 1 foot longer than the span between setts.

Excavation.—As for entrances, always break to a "cut."

11. **Chambers.**—Pillars of solid ground of a minimum thickness of 12 feet in chalk and 20 feet in clay, must always be left between chambers.

In ordinary soil, chambers should be excavated 9 feet wide and timbered and the roof supported with standard R.S. joists on pit props. In clay or soft chalk the joists require intermediate props, which should be inserted afterwards. They need not be placed in the centre of a girder but should be arranged to facilitate bunking, &c.

The general rule for spacing girders is at 2-foot centres in clay or sand, and at 2-foot 6-inch to 3-foot centres in chalk.

To prevent the side props from being pushed inwards they are connected to the girders by clips or brackets. The usual patterns are shown on Plate **148**, Figs. 4, 5 and 6. The clip shown in Fig. 6 must be fixed when the girder has been put in place. Props should not be weakened by notching them.

Girders must be side-strutted to prevent them rolling over and buckling. Four struts of 4-inch by 3-inch timber are wedged between one girder and the next, spaced at intervals of 3 feet along the girder. They must be wedged extremely tight.

In clay, loam or sand, foot blocks 12 inches by 12 inches, or in heavy ground, groundsills are necessary. In good chalk it is sufficient to let the prop 3 inches into the floor.

12. Excavation and timbering.—Except in very solid ground spiling should be employed (Plate **156**). Apart from the danger to men working if any falls occur, they not only delay progress but seriously weaken the overhead cover.

The excavation of the whole face in one piece should not be attempted. Two methods are suggested below :—

No. 1 Method.—First drive a pilot gallery. The most economical size is about 5 feet by 2 feet. This should be timbered and be approximately in centre line of chamber. Such a gallery serves as a useful check on levels and direction.

In connecting between two entrances it is as well to push this right through and secure through ventilation prior to starting the chamber proper. Men work much faster in a well-ventilated gallery. Where speed is very important, however, the face of the chamber can be worked at when this gallery is 10 feet in advance of it. The gallery then forms a " cut " to which the sides of the chamber are broken. Two men can work on each side.

No. 2 Method (without a pilot gallery). Cut out the sides of the chamber 2 feet 6 inches wide and the full height, driving forward the spiling boards over this area first. When both sides are removed to a sufficient depth to set the next props, cut out the top of the centre buttresses driving spiling boards forward as before. Then catch up these boards by a beam underneath, supported on either side of the buttress by pit-props. Set forward girder, distance pieces, whaling board and wedges and then pick out the centre buttress.

13. **Drainage.**—In wet ground, *i.e.*, where pumping is necessary, the water in the dug-out should be collected into one or more definite sumps. Correct levels are, therefore, of the greatest importance, and skilled assistance will probably be necessary. The chambers should be 1 foot higher than the gallery and should drain towards it. Galleries should have a fall of 1/50 towards the sump to counteract small errors in setting the frames.

Trench boards should never be allowed in galleries. They collect filth and obstruct the drainage. To ensure cleanliness, when the difficulties of transport are not too great, the floors of chambers and galleries may be covered with a layer of fine concrete, 1 inch thick, laid on expanded metal which is nailed to the ground sills.

To prevent the roof of a dug-out leaking in shattered chalk, all shell-holes above it should be filled in so as to develop a slight mound.

14. **Ventilation.**—Ventilation is best assured by adopting type "B" for men's quarters (Plate **154**, Fig. 2), and, in big systems, by siting the kitchens so as to assist ventilation.

Vertical shafts, when used, should be utilized as kitchen flues and sited accordingly. In chalk, sound earth, and clay, holes should be bored to the surface to take kitchen flues and to assist ventilation. Special precautions must be taken to prevent gas entering by the bore holes.

15. **Bunking.**—A method for a 9-foot chamber is shown on Plate **154**, Fig. 2; it provides a seat and a blank wall for hanging kit.

Bunks should be 6 feet 6 inches by 2 feet. This governs the length of the chamber. The cubic air space available allows for three tiers of bunks in chambers 8 feet wide, but only two tiers in chambers 6 feet wide.

16. **Gas curtains.**—(Plates **157** and **158**). Gas protection is dealt with in Sec. **66**.

17. **Protection against grenades thrown down the entrance.**—A wire netting screen placed a few feet down the incline prevents the grenade going down the incline or causes it to rebound into the trench. Bomb traps should also be constructed at the foot of all inclines. The bottom of these should be about 3 feet below the level of the floor of the gallery.

18. **Working parties and footage.**—The usual working parties, exclusive of those employed in disposal of the spoil on the surface, are given below:—

Inclines.

1 man picking.
1 man filling sandbags.
1 man carrying for each 10 feet of entrance.

Progress for each shift of 8 hours should be about 2 feet 6 inches.

Galleries.

1 man picking.
1 man bagging. } Reliefs for men at face.
1 man assisting.

NOTE.—Two reliefs are necessary if a fair advance is expected.

Progress for each shift of 8 hours should be about 3 feet, and approximately 300 bags for each shift will be produced.

Carrying party.

1 man can carry 100 bags along 100 feet of gallery for each 8 hour shift.
1 man can carry 100 bags up 10 feet of entrance for each 8 hour shift.

The best method is to work in relays every 30 to 40 feet of gallery and every 5 to 7 feet of entrance.

Chambers.

No. 1 Method.

1 man picking in pilot gallery.
1 man filling in pilot gallery.

Unless speed is of first importance this gallery is driven in advance. Progress should be 4 feet for each shift of 8 hours.

Provided the pilot gallery has been or is being driven :—

Men employed on chamber face :—

2 men picking.

4 men filling bags, setting and supporting timber. These men provide reliefs for pick men.

Progress for each shift of 8 hours should be about 2 feet 6 inches, and approximately 560 bags will be produced.

Carrying party calculated as above.

No. 2 Method.

2 men picking.

4 men filling and timbering, who relieve picking men as they tire.

Progress for each shift of 8 hours should be about 2 feet, and approximately 450 bags will be produced.

Carrying parties calculated as above.

Surface party.—The number of men dumping depends on nature of dumps and distance of carry.

1 man can carry 100 bags 200 feet in 8 hours on surface under ordinary trench conditions.

Labour underground can be economized by the use of trolleys and windlasses.

PART IV.—COMMUNICATIONS

CHAPTER XV

CROSS-COUNTRY TRACKS, ROADS AND TRAMWAYS

107. *Cross-country tracks.*

1. **Cross-country tracks** are made for the following reasons :—

i. To relieve congestion on main roads by taking all foot and horsed traffic off them, at any rate in dry weather, and so leave them for those vehicles which cannot go across country.
ii. To avoid villages and other shelled areas ; these are sometimes called "avoiding" tracks.
iii. To improve and shorten communications generally.

All tracks must be reconnoitred, pegged out, roughly levelled, drained, and provided with signposts at frequent intervals. Battery positions and conspicuous points which draw fire must be avoided.

2. **Marking of tracks.**—All tracks must be well marked, so as to be easily followed, both by day and by night.

Tracks can be marked in the following ways :—

i. By posts.
ii. By notice boards.
iii. By a tape line.

Posts should be painted white. Halved pickets painted white on the sawn face, or screw pickets to each of which a tag of canvas has been tied may be used.

Posts should be spaced at 20 yards interval ; they should be closer together at corners and difficult places. If both sides of the track are marked, the posts should be placed opposite each other in pairs, not chequerwise. A horizontal wire or tape should be fixed between the tops of the posts ; the wire should have short lengths of tape tied to it at 4 feet or 5 feet intervals, otherwise men will not see it.

Notice boards.—Notice boards may be substituted for posts. They have the advantage that each one can be marked with the name, letter, or number of the track, and map references at important points ; black letters on a white ground are better than white letters on a black ground. For infantry tracks they should stand 3 feet out of the ground ; for mule tracks they should not be higher than 18 inches or they will be knocked over by the passing loads.

"Up" and "Down" tracks must be clearly marked and the names of any places near which the track passes should be marked on notice boards clearly visible from the track.

Tapes.—Tapes are only a very temporary expedient; they are soon obliterated by mud, and should not be laid earlier than the afternoon before they are required; they cannot be relied on for more than 12 hours, unless they are raised from the ground. This can be done by running them through the eyes of screw pickets. They are of use to troops on the night after an advance for marking the way from the company H.Q. to battalion H.Q., and from battalion H.Q. to tracks leading to the rear.

Lanterns.—Screened lanterns are useful at junctions and important points. They can be made with candles or small oil lamps in perforated biscuit tins with calico shades.

Maintenance of posts and notice boards should be done by the track wardens, detailed for the purpose.

3. Cross-country tracks are of three kinds:—

i. For men.
ii. For pack animals.
iii. For horsed transport.

4. **Tracks for men.**—The most satisfactory track is one made of trench boards. Trench board tracks should avoid mule tracks, or the temptation to lead mules along the trench boards will be irresistible.

A trench board track should be 3 feet wide to enable men to move along it rapidly on a dark night without risk of falling off. A one-way track should first be completed; as soon as possible, this track should be duplicated to give an "up" and a "down" route; the tracks should not be within 200 yards of each other; direction boards must be erected at the terminals and at all places where the tracks cross lateral routes. The number of tracks required depends on the tactical situation, but two pairs (*i.e.*, two "up" and two "down") for each brigade front should suffice.

Lateral communication between tracks should be provided, especially in heavily-shelled areas.

In crossing ridges, the track should be laid in a trench of a sufficient depth that men do not show against the sky line. Trench boards should be laid on 3-inch by 1¾-inch transoms bedded in the ground; if laid on trestles, they are much more liable to damage by shell fire, and men fall off the track at night. Trestles, however, are necessary in swampy ground, in which case they should be raised from the ground but kept as low as possible to give an even track.

To prevent slipping, stout wire netting should be carefully fixed. No. 8 or No. 10 S.W.G. wire has also been found satisfactory. It should be well stapled down in a diamond-shaped pattern 6-inch to 8-inch mesh. Expanded metal and "rabbit netting" quickly wear out and then cause men to trip.

In sandy soil, a quickly-made and efficient track may be obtained by spreading out rolls of wire netting (¾-inch to 1-inch mesh) directly on the ground and pegging firmly down.

When brushwood is available in the immediate vicinity, marshy ground may be crossed by means of brushwood mats, made of 1-inch rods.

Permanent track wardens must be appointed to repair damage.

5. **Tracks for pack animals** should be made at the same time as the tracks for men. They consist of an earth formation on the best ground available; the route which involves the least earthwork should be chosen.

Two single tracks are better than one double one, but they should be clearly visible from each other and connected by switches at frequent intervals in the same way as trench board tracks (*see* para. 4). Loops should be made at all dumps.

Infantry trench board tracks should be avoided (para. 4); special duck boards for mules with 1½-inch decking may be provided.

The formation should be 4 to 5 feet wide for single traffic, or 8 to 10 feet for double. If less than 4 feet wide the mules will slip off.

Shell-holes must be cleared of water before being filled in, otherwise the filling will always be a soft place in the track.

Surface drainage must be provided, by means of a ditch on each side of the track discharging into large shell-holes; box drains should be put in where necessary.

Mules' feet are small, and, in wet weather, readily sink into soft ground, rendering it impassable in a very short time. The following methods have been found suitable for crossing boggy patches of ground :—

i. Fascines, with a layer of earth on them to prevent shoes being pulled off.
ii. Hurdles.
iii. Corduroy of logs.
iv. Beech slabs laid on longitudinal runners.

6. **Tracks for horsed transport** can be used by vehicles in fine weather only, and it may even then be necessary to follow roads for short distances to avoid boggy places. It is very important to fix notice boards where the track enters and leaves the road. These tracks are similar to tracks for pack animals, but should be 18 feet wide and marked out on both sides. Side drains are particularly important.

When making a track across trenches, bridging should be resorted to only when absolutely necessary, *e.g.*, when the trench must be kept open or is too big to fill in.

When the track crosses a trench obliquely, it may be necessary, for the sake of speed, to make the track, in the first instance, at right angles to the trenches. In such cases the track should subsequently be made straight as soon as possible. These crossings should be made with corduroy or fascines. Wheel guides and handrails should be provided.

If a track crosses a road, a length of 30 yards on either side of the road should be laid with fascines to prevent mud being carried on to the road.

108. *Roads.*

General principles.—The object of a road is to present a hard, even surface for traffic. A hard surface can be obtained by using hard stone or hard woods. Soft stone, earth, clay, or anything that is soft or will turn into mud must be avoided. The interstices in the surface of a road should be filled with gravel, stone chippings, or sand.

To present an even surface, the road must have good foundations, otherwise time and traffic will cause settlements and depressions.

The foundations may give way by being too weak, or by the failure of the earth formation below. They should be composed of a layer of large stones, 9 inches thick, which traffic will not hammer into the earth formation.

The earth formation below the foundation may give way by getting water-logged and soft; it must be kept dry by longitudinal drains, the bottom of which are below the lowest part of the foundation and by the camber of the formation.

The surface of the road is kept dry by the camber, *i.e.*, by making the centre higher than the sides, so that rain is at once thrown off; otherwise water will lodge in ruts and holes and soak through the surface and foundation into the earth beneath.

109. *Metalled roads.*

1. **Metalled roads.**—The operations of constructing a road are—

i. Peg out centre line.

ii. Mark out side drains.

iii. Throw the earth excavated from the drains into the centre of the road, so as to form the camber, getting additional earth if necessary from borrow-pits outside the drains. Ram this earth (Plate **159**, Fig. 1).

iv. Lay foundations, or soling stones, by hand, carefully packed, not forgetting the outer wall of soling stones laid in a trench to prevent the road spreading (Plate **159**, Fig. 2). Soling to be 6 to 9 inches thick, according to the subsoil.

v. Lay broken stones or macadam (2-inch to 2½-inch gauge) in 4½-inch layers, and roll well in. If possible, lay a second similar layer and roll well in.

vi. Finish off surface by rolling in stone chippings, gravel and, at the very end, a little sand.

vii. Put in 6-inch posts close up to the haunches of the road to prevent traffic leaving the metal.

They must be at a slope of 6/1 and should be whitewashed.

2.—i. **Camber** should be 1/30 to 1/40. Too much camber is very inconvenient to wheeled traffic, causing it to slip off the road.

ii. Templets (Plate **159**, Fig. 1) must be used in making the earth formation and in laying and rolling road metal.

iii. Single-way traffic requires a minimum width of 9 feet of road metal; double-way traffic a minimum width of 18 feet.

iv. On a single-way road, passing places, 50 yards long, must be made at ntervals of 400 yards. With a double-traffic road on a hillside, pickets 4 to 6 inches in diameter should be driven in every 6 feet on the outer edge with rough plank revetment to stop the road spreading (Plate **159**, Fig. 3).

v. As the centre of the road takes the most traffic and gets most hammering a greater thickness of metal can be put there than at the sides and the camber thus be improved.

vi. Roads on sloping ground must never be graded to drain right across from the higher to the lower side of the slope. They should be cambered in the usual way and, when necessary, box culverts provided under the road to evacuate the drain on the uphill side (Plate **159**, Fig. 3).

Where roads cross drains, catch pits for silt should be made in the drains to prevent them from becoming blocked and flooding the road. The catch pit should be made well clear of the road and above it and should be protected by fencing or a strong cover.

It should be large enough to enable a man to get into it to clean it out, and its depth should be at least 2 feet below the outlet. Catch pits should be revetted with timber, corrugated iron, or more permanently with brick.

They should be cleaned out periodically and invariably after heavy rain.

3. After a severe frost, **thaw precautions**, *i.e.*, suspension of heavy and fast traffic, are necessary on all metalled roads on which there is much traffic; these precautions may last several days.

A frost followed by a thaw has a tendency to disintegrate the material of which a roadway and its foundations are made, with the result that the roadway would break up under heavy and fast traffic; chalk is especially liable to this process of disintegration.

4. **Maintenance.**—Every road requires a small maintenance party or it will soon go to pieces. Small neglected ruts become enormous holes under heavy traffic in a few days. Water and mud left on the surface of roads quickly destroy them.

5. **Repairs and improvements.**

i. Many roads are developments of old tracks, and in consequence are "sunk" roads. They are watercourses instead of watersheds (Plate **160**, Fig. 1).

This type of road requires reconstruction to re-establish the drainage. This can often be effected by one of the methods shown on Plate **160**, Figs. 2 and 3.

ii. In clay country the clay, in wet weather, works up through badly made roads and destroys them.

This can be prevented by a 6 to 9-inch layer of chalk beneath the foundation of the road; this chalk should be well rammed until it is smooth. Small broken chalk is better than large hard pieces as it consolidates better; this chalk forms a seal. Sand may be used in place of chalk.

iii. When widening existing country roads in a clay country dig out the earth berms in short lengths, deep enough to allow of (*a*) chalk layer; (*b*) soling; (*c*) road metal, but still preserve the camber. If the traffic is not of the heaviest, *e.g.*, heavy artillery, tractors, &c., the chalk (if not less than 9 inches thick) may replace the soling.

The treatment is the same in the case of roads paved with setts, which are always laid on sand (Plate **161**, Fig 1).

iv. **Ruts.**—Cut the rut out square; if the foundation of large stone has been destroyed, replace it by hand packing soling stone and then lay and ram the surface layer of macadam. In clay country, be careful to renew the chalk layer beneath the foundation whenever it shows signs of destruction. Shell-holes require similar treatment (Plate **161**, Fig. 2). Never cut away the earth berm of a road even if it is liquid mud, without immediately replacing it with chalk or stone. To leave a void for even 24 hours will cause great damage to the metalled centre by allowing it to spread.

v. In taking over the maintenance of an existing metalled road in poor condition the following is the order of urgency of work:—

(*a*) Establish longitudinal side drains and cut wide gaps through the banks of earth, mud and rubbish so that the water will drain off the road. Never dig away the earth berms.

(b) Sweep mud and water off the road into the side drains; use brooms for this, not scrapers or shovels.

(c) Deposit all solid mud, debris and spoil clear of the drains and on the far side.

(d) Repair the worst ruts first by cutting out square and filling in, as explained above, taking care to ram well.

(e) If sufficient stone is available restore shape and camber to the surface. To do this, treat half the width of the road at a time, length by length. Pick up the surfaces with pick-axes, spread macadam to the required thickness and section (using a templet), and roll well in. Unless the old surface is picked up the new layer of stone will not key into the old and will soon break up.

(f) If it is found that the road is worn concave and that the chalk foundation has disappeared, it will be necessary to cut out a fresh camber in the subsoil and reconstruct the road on this (Plate **161**, Fig. 3).

6. **Craters.**—The deviation made round a shell or mine crater to allow traffic to pass in the first instance, must be made clear of the debris on the lip of the crater. This debris is required for filling in the crater.

To fill in a large crater:—

i. Remove all sludge or water.

ii. Fill to within 1 foot 6 inches or 2 feet of the surface with alternate courses of filled sandbags and rammed dry earth; or fill with rammed dry chalk. The use of sandbags for this is not economical.

iii. Then lay a slab roadway, as described in Sec. **110**.

Tightly filled sandbags covered with wire netting or expanded metal on which is placed 3 or 4 inches of road metal will form a practicable road for lorries.

Whatever hard material is available, *e.g.*, broken bricks, chalk, &c., must be reserved for filling the top portion of the crater; the bottom part should be filled with softer material.

A method of dealing with small shell craters is described on Plate **161**, Fig. 2.

7. **Causeways** are used for road crossings over small streams, where bridging operations are unnecessary.

A causeway consists of (i.) a culvert to carry off the water, (ii.) a filling of earth or other material to bring the surfaces of the road to its correct level.

i. The culvert may consist of—

(a) Bundles of brushwood, fascines, large stones, &c., where only a temporary crossing is required.

(b) 12-inch wooden box drains made of 2-inch timber, which is generally procurable.

(c) 2-foot or 18-inch corrugated iron culverts which give the strongest form of drain.

(d) Earthenware or concrete pipes, which require care in bedding and time to lay.

The size of the culvert required depends on the width and velocity of the stream, and the amount of water to be carried off, full allowance being made for floods.

The culvert should be laid on a firm and level bed, slightly above the original level of the bed of the stream.

Wing walls are required to prevent a false passage of water.

The inlets of small culverts must be protected by screens of wire netting to prevent them from being choked.

ii. Earth filling.—When the culverts have been laid, soil is thrown on and well rammed until a height of 6 inches above the correct level of the roadway is reached; this will allow for settlement.

The sides of the earth filling should be 1/1, and must be revetted as the work proceeds with timber and poles (Plate **162**).

A sleeper or corduroy road, as detailed in the next section, is laid down, the width of the top of the causeway being 15 feet and the roadway 10 feet in the clear.

Handrails and curbs should be added.

8. Plate **162** shows the details of a causeway capable of carrying a tank. Handrails and curbs are omitted.

110. *Slab, sleeper and corduroy roads.*

1. The road may be:—

i. A single-way road.
ii. A single-way road, which is to be doubled when circumstances permit.
iii. A double-way road.

A single-way road is 10 feet wide and a double-way is 20 feet wide.

Slabs, sleepers and logs are usually supplied in 10-foot lengths.

Slabs are of hard wood (beech) 2 inches thick; sleepers are 3 to 4 inches thick, usually of fir; corduroy of round logs split in two.

2. **A double-way track** must provide—

i. A hard surface, which is provided by the hardwood used, *e.g.*, beech.
ii. An even surface, which must be ensured by sufficiently strong and well-drained foundations.

3. To ensure drainage—

i. *The roadway must be above the general level of the ground.*
ii. Side-drains must be cut; and
iii. Surface water must be thrown off by raising the centre of the road.

4. The **foundations** must be made of sufficient layers of fascines, or timber baulks or sleepers to prevent the traffic from hammering the surface into the ground, or making it wavy. The foundations, in fact, must spread the weight of the traffic. The finished camber should be rather less than with metalled roads, about 1/40 to 1/60.

5. A double corduroy or slab road is made as follows (Plate **161**, Fig. 4):—

i. Peg out centre line.
ii. Mark out side drains.

iii. Excavate the drains deep enough to drain the earth formation, throw the earth into the centre of the road and ram.

iv. Excavate for the reception of the outer ends of the sleepers.

v. Lay the sleepers at the proper slope, allowing for an initial camber of 4 to 6 inches. Traffic will reduce this to the final camber of 2 to 3 inches. Fill in between with earth, and ram.

vi. Lay the runners so that they break joint and dog the two centre ones together. Spike all runners to the sleepers. The holes for spikes and dogs must be bored with an auger, otherwise the wood will split. Fill in between runners with earth, and ram.

vii. Lay the corduroy close, round sides uppermost, and spike each log to every runner.

viii. Lay the ribands, with a gap of 1 foot every 30 feet, to allow for drainage, and spike or dog them to the corduroy and pickets.

ix. Pickets should be fixed when the runners are laid, but may be added later.

6. **Earth berms** preserve the side drains and permit of the passage of foot and rider traffic. They should be at least 4 feet wide.

7. **Single-way track.**—In laying a track 10 feet wide, the above procedure is followed, except that the corduroy is laid flat.

Corduroyed passing places must be provided every 400 yards.

On hard ground, or for light traffic, the sleepers may be omitted. Fascines can be substituted for sleepers.

In swampy ground a layer of fascines close together, laid in the same direction as the sleepers, viz., across the road, must be put down first. The sleepers will squeeze in between the fascines and ensure the runners having a continuous smooth bearing on the fascines. Ribands should be about 6 inches by 6 inches, or 6 inches in d ameter.

8. **Turning places.**—Provision must be made for turning places at all points at which wagons or lorries may have to unload. These turning places must be made just like the roadway (Plate 161, Fig. 5).

Where "in" and "out" roads to depots branch off, and at "refilling points, the opposite side of the main road may require widening, to enable lorries to proceed in either direction. A turning radius of 10 yards should be allowed.

9. **Converting corduroy roads to metalled.**—The corduroy must be taken up except when it has sunk into soft ground, and it is possible to lay a full thickness of foundation stones and macadam on top. The old corduroy in this case improves the foundations of the roads.

111. *Tramways in forward areas.*

1. **Purpose of tramways.**—Tramways are required, often in extension of light railways, for the carriage and distribution of ammunition, engineer stores, rations and personnel.

They are a means of getting ammunition up to battery positions situated away from roads, of supplying engineer dumps with material, of feeding the troops, and of transporting working parties to and from their destination, &c.

The purpose for which a tramway is required should be clearly defined before work is begun.

Tramways should, if possible, be run on grades that can be taken over by the light railways, thus ensuring as little break as possible in communication.

2. **Types of tramways.**—There are two types of tramways, the 9-lb. 60-cm. track with steel sleepers and the 20-lb. 60-cm. track with steel sleepers, or a combination of steel and wood sleepers. The former type is used for push tracks or mule haulage and the latter for power haulage.

9-lb. or 20-lb. track means that the rails weigh 9 lbs. or 20 lbs., respectively, for each yard length of single rail.

Both types of tramway are supplied by the mile, and include a proportion of curved rails and turnouts.

3. **Description of track.**—9-lb. track is made up in the following proportions for each mile (Plates **163** and **164**) :—

Item.	No. of sleepers for each section.	Sections for each mile.	Length for each mile.	Weight for each section.
			metres.	kilos.
5·00 m. straight sections ...	5	290	1,450	65
2·50 m. straight sections ...	2	64	160	33
2·50 m. curved sections ...	2	40	100	33
Turnouts—				
Right-hand...	—	6	30	130
Left-hand	—	6	30	130
				Tons.
Total for each mile ...	—	—	1,770	24·2

The rails are secured to the sleepers by means of hook or clutch bolts, which clamp the flanges of the rails to a lug or plate which is riveted to the sleeper (Plate **163**, Fig. 1).

In addition to the sleepers, each track section is provided with one joint plate which serves the double purpose of supporting the rail ends as a sleeper and joining the ends of the two adjacent track sections by means of hook or clutch bolts (Plate **163**, Figs. 2 and 3).

The curved sections are all of 15 metre (49 feet 3 inches) radius (Plate **164**, Fig. 3).

The turnouts are issued ready-made up in one piece (Plate **164**, Fig. 4), and all sleepers are riveted to the rails, thus requiring no assembling. The turnouts are 5 metre (16 feet 4⅞ inches) long overall, so that they can be laid in at any point in existing tracks without cutting closing rails.

Turntables are special stores which must be ordered separately. They are 4 feet in diameter for trucks whose wheelbase is not greater than 3 feet 4 inches. Turntables should be laid at the same time as the track to obviate cutting closing rails.

4. **20-lb. track** is made up in the following proportions for each mile (Plates **165** and **166**) :—

Item.	No. of sleepers for each section.	Sections for each mile.	Length for each mile.	Weight for each section.	
				Type A.	Type B.
			metres.	kilos.	kilos.
5·00 m. straight sections	9	210	1,050	265	199
2·50 m. straight sections	9	104	260	141	108
2·50 m. curved sections, 30 m. rad. ...	5	40	100	141	108
5·00 m. curved sections, 30 m. rad. ...	9	10	50	265	199
5·00 m. curved sections, 50 m. rad. ...	9	20	100	265	199
5·00 m. curved sections, 100 m. rad.	9	10	50	265	199
Turnouts—					
Right-hand	—	5	37·5	516	546
Left-hand	—	5	37·5	546	546
				Tons.	Tons.
Total for each mile	—	—	1,685	91·3	71·9

Type A (Plate **165**, Figs. 1 to 4), used only in bad ground, consists of 20-lb. rails secured by bolts and clips to steel sleepers (Plate **165**), 5 for each 5 metre length and 3 for each 2·5 metre length, and these sections are laid on wooden sleepers and spiked thereto—4 wooden sleepers for each 5 metre length and 2 for each 2·5 metre length.

Type B (Plate **165**, Fig. 5) consists of 20-lb. rails secured by bolts and clips to steel sleepers, 9 for each 5 metre length and 5 for each 2·5 metre length.

The sections are joined together by means of fishplates and bolts—4 bolts to each pair of fishplates, the bolt heads always being placed on the inner side of the rail to prevent the flanges of the wheels striking the nuts.

The 20-lb. turnouts (Plate **167**) are issued in three pieces and are made right-and left-handed. A right-hand turnout is one which branches off to the right when viewed from the switch end looking towards the siding or frog end.

In order that mules can haul trucks without damage to the track, "mule walk" grids can be laid on the sleepers (Plate **168**). Mules must not be allowed to walk on the track unless these mule grids are provided.

A somewhat lighter form of grid can be substituted when only man haulage is used.

5. **Location.**—Lines to be located are marked out as nearly as physical features of ground permit in straight lines from point to point with a maximum gradient of 2 per cent. (1 in 50), or, if quite unavoidable, 3 per cent. (1 in 33), and the sharpest curve for 20-lb. track, 30 metre radius. This sharp radius curve should never be used if it is possible to put in a curve of easier radius. In 9-lb. track the only standard curve provided is 15 metre radius, which is suitable for the traffic which it is intended to carry.

The shortest line is not always the quickest to construct or the easiest to operate.

A thorough reconnaissance and staking out of the line should always be done well in advance of the earth work.

The following points should be noted:—

i. Take fullest advantage of cover from enemy observation, even if it involves a detour, or negotiating features mentioned in (iii).
ii. Bogs, marshes, oblique crossings of streams and roads; long cuttings must be avoided.
iii. Avoid localities such as cross roads and prominent objects which attract shell fire.
iv. All grades should be in favour of the load.
v. Tracks must be sited to suit the standard curves provided, *i.e.*, 30, 50, and 100 metre radius, and with 9-lb. track, 15 metre.
vi. Main lines in forward areas should never go direct to large dumps, batteries or headquarters, but should connect with these delivery points by means of branches or spurs at least 200 yards long.
vii. Lines should never be constructed along the sides of a road surface. It leads to congestion of traffic and damage to the line.
viii. Lines should always be located with a view to draining of formation level, *i.e.*, they should not go up the centre of a valley, but should be constructed a little up the side slopes.

6. **Construction.**—i. A convenient site must be selected for taking delivery and assembly of the track. From this point the complete sections are transported over the newly-formed track to the track-laying party.

In laying 9-lb. track in forward areas the parties should be kept as small as possible, and "bunching" should be avoided.

A typical distribution for a party of 32 men is shown below:—

	N.C.Os.	Men.	Tools and stores.	
(a) Preparing ground	1	11	Shovels	12
			Picks	4
			Billhooks	3*
			Axes, felling ...	2*
			Wire-cutters ...	2*
(b) Loading and pushing	1	9	Push trollies ...	4
(c) Carrying and laying	1	9	Spanners	4
			Picks	2
			Hammers, 6-lb. ...	2

100 to 150 yards an hour can be laid by this party if materials are delivered at the near end of the line.

The above is for a maximum push of 500 yards. Add 2 men and a trolley for each 200 yards to this party for longer pushes than 500 yards.

A typical distribution for a party of 100 men to lay 20-lb. track is shown on next page.

* Required in special cases only.

	N.C.Os. or skilled men.	Men.	Tools and stores.	
(a) Forming formation level	2 N.C.Os.	60	Picks ... ... Shovels ... ... Wheelbarrows ...	20 30 8
(b) Laying track	2 platelayers	10	Steel crowbars ... Spanners ... ... Beater picks ...	2 2 4
(c) Carrying track sections	1 N.C.O.	20	Push trucks ...	5
(d) Assembling track	1 Fitter	10	Spanners	8

This party of 100 men should lay 100 yards of 20-lb. track an hour under normal conditions: this does not allow for ballasting.

ii. Passing points should be allowed every $\frac{1}{2}$ mile.

iii. In the first instance, as little earthwork as possible should be undertaken, and the line laid on the natural ground and opened to traffic as soon as possible. This line can then be improved as labour becomes available.

iv. Provided that drainage is properly developed, tramways for light rolling stock should not require ballasting. A useful roadbed can be made of chalk if available, provided it is thoroughly well drained. Shell-holes should be used for drainage purposes.

v. In passing over very soft ground, the steel sleeper can be supplemented by wood sleepers, and in the worst cases raft track, as shown on Plate 169, can be used.

vi. Three typical cross sections are shown on Plate 170 for the cases of construction on level ground (Fig. 1), embankments (Fig. 2), and in cuttings (Fig. 3), respectively.

vii. Road crossings should be constructed with wood sleepers, to enable guard rails and 2-inch longitudinal planks to be spiked to them (Plate 171). When crossing roads which carry heavy traffic, 20-lb. rail should always be used, even though the track is otherwise constructed of 9-lb. rail.

7. Maintenance.—A tramway track in operation requires frequent inspection; at least once in every 24 hours, and also after every bombardment.

Repairs must be made **immediately** they become necessary.

The points to be looked for in ordinary inspections are—

i. Bad packing, water lying on track, rails not at correct levels or alignment, sleepers buckling.

ii. Adjustment, cleaning and draining of points and crossings.

iii. Clutch bolts, in the case of 9-lb. track, and fishplates and clip bolts in the case of 20-lb. track, working loose.

Materials for maintenance and repairs to track should be distributed for use of the maintenance gangs at convenient points for quick access, and should always include a proportion of curves. All salved track material should be collected at the same points and returned on trucks which have conveyed up new material.

The quickest way to repair a line which has been cut by a shell or bomb is to cut out the damaged rail sections complete and replace by new rail. A large shell-hole is best dealt with by diverting the track round it; a small one, by filling or bridging with timber or steel, as available.

8. **Control of rolling stock.**—Issue and despatch of trucks must always be controlled at loading points. The senior man in charge of the haulage party should sign for the trucks as issued by the traffic control N.C.O., and should also report and explain all breakages and deficiencies when he returns.

The traffic control N.C.O. should be in possession of a copy of his orders and duties. He should at once report to higher authority any non-compliance with traffic standing orders, in order that the efficiency of his section may be maintained.

9. **Operating forward tramways.**—To ensure the efficient working of the system an officer must be appointed as officer in charge tramways; to this officer will be sent all indents for trucks, giving number of trucks required, time, place where required, and loads to be carried; when the number of trucks is insufficient to meet all requirements, preference will be given to heavy articles which cannot be split up into one-man loads, such as girders, &c.

The officer in charge tramways must insist upon the following rules being carried out:—

i. Haulage parties must be detailed in addition to working parties.
ii. Riding on trucks is forbidden.
iii. Empty trucks give way to loaded trucks.
iv. Damaged trucks must be returned to the tramway centre.

An efficient system of reporting breaks in the lines, &c., must be arranged.

PART V.—DEMOLITIONS

CHAPTER XVI

EXPLOSIVES AND DEMOLITIONS

112. *Explosives.*

1. **Low and high explosives.**—Explosives are classified as low or high explosives according as to whether they function by the process known technically as "explosion" or by that of "detonation."

Explosion is a rapid form of combustion, normally started by ignition, and the action of low explosives is a comparatively slow one, producing a more or less steady pressure or lifting effect. Such explosives are used in warfare as propellants.

Detonation, on the other hand, is a far more sudden change from a solid to a gaseous state, which takes place almost simultaneously throughout the whole bulk of the explosive. As a result high explosives are intensely rapid in action, and cause violent local and shattering effects, properties which render them suitable for demolition purposes. In modern warfare, therefore, high explosives only are used for work of this nature. The more sensitive high explosives can be detonated, either by ignition or percussion, but the stabler forms and, therefore, those which can be used in bulk with safety, can only be detonated satisfactorily by severe shock, their tendency when ignited being to burn instead of to detonate.

2. **Bulk explosives.**—The following explosives are typical of those which will normally be available for use in bulk on service:—

i. Wet gun-cotton.
ii. Ammonal.
iii. Dynamite.

i. **Wet gun-cotton** is compressed nitro-cellulose, damped with 15 to 20 per cent. of water. The addition of the latter renders it safer to store and handle, and increases its effect on detonation. It is issued in 1-lb. slabs, 6 by 3 by 1½ inches in size, provided with a tapered 1¼-inch hole for the reception of a gun-cotton primer. It is packed in sealed tin cases containing 14 slabs each.

Gun-cotton is a very powerful and rapid explosive producing great shattering effect, while owing to the form in which it is provided, it is easily and quickly fixed in position. It is therefore well suited for demolitions requiring comparatively small quantities of explosive, in which close contact with the object to be destroyed is essential, as for instance, the destruction of rails or girders. Complete detonation of gun-cotton, if used in large mined charges, is not always certain and its action in any case is rather too rapid to produce a good lifting effect.

ii. **Ammonal** is a grey composite powder. It is issued in damp-proof tins containing 25 lbs. and 50 lbs. Ammonal deteriorates rapidly with exposure as it absorbs moisture readily, and it should not be left in a damp place for any length of time, except in the damp-proof tins.

Ammonal is about as powerful as gun-cotton, but, being rather slower in action, produces a better lifting effect in the case of mined charges, for which it is specially suitable. As ammonal is a powder, it must be placed in a container, when used for small charges requiring accurate fixing and close contact. For this reason, and from the fact that its shattering effect is rather less, it is not so well adapted for demolitions of this nature as gun-cotton.

iii. **Dynamite** is a plastic explosive, used extensively commercially for blasting rock in mines and quarries. It is manufactured in several forms gelignite, gelatine dynamite, blasting gelatine, &c. It is usually issued in 2-oz. cartridges wrapped in parchment paper and packed in boxes weighing 5 lbs. and 50 lbs. Dynamite cannot be used after exposure to wet, which separates the ingredients and makes it dangerous to handle. Dynamite freezes at 40° F., and remains frozen at higher temperatures. Complete detonation is impossible with froen dynamite. Frozen dynamite can be distinguished from unfrozen, because it is harder, more brittle than plastic, and of a slightly lighter colour. It should be thawed before use, but this is a dangerous operation and should be left to experts.

Dynamite and its modifications are the most powerful explosives in practical use and their action is even more local and shattering than gun-cotton. They are not so safe to handle or to store as wet gun-cotton or ammonal, but being plastic, and of such power, they are specially adapted for use in small bore-holes and narrow and irregular spaces where it would be difficult to fit a charge of gun-cotton.

3. **Other explosives**.—Numerous other high explosives used commercially may become available on service. The mode of action and method of use of such will, however, in general be similar to those described above.

4. **Methods of firing**.—Explosives may be fired by:—

i. *Safety fuze*.—The service safety fuze No. 11 consists of a train of gunpowder in a waterproof covering, and is packed in flat cylinders containing 8 fathoms. It burns at the rate of about 2 feet a minute, but, as this rate is liable to vary, it should be checked before use by burning a measured length and timing it. Safety fuze will burn under water.

ii. *Electricity*.—By this means charges can be fired from a distance, leads from an exploder being connected to the electric detonator or detonators in the charge. Electrical methods of firing are explained in Sec. 115 and more fully in Military Engineering, Vol. IV.

113. *Auxiliary explosives—primers, detonators, &c.*

1. **Fulminate of mercury** is a highly sensitive and violent explosive, too dangerous to use in any but very small quantities. It detonates with slight friction or percussion and readily on ignition. It is owing to the latter fact that it is used in the form of detonators, as a medium for the detonation of bulk explosives by ignition.

2. **Detonators.**—Two forms of detonators are used for explosives on service :—

i. The No. 8 detonator for use with safety fuze. It consists of a cylindrical copper tube, $2\frac{1}{4}$ inches long and $\frac{7}{32}$-inch in diameter. The lower end is closed and $1\frac{1}{4}$ inches of the tube is filled with fulminate of mercury composition; the rest of the tube is left open to receive the fuze. The fuze placed in the open end of the tube burns down to the fulminate, ignites it and causes it to detonate. No. 8 detonators are painted red and are packed in red tin cylinders containing 25.

ii. The No. 13 electric detonator. This is a fulminate of mercury container like the No. 8, to which it is similar in action, but the method of igniting the fulminate is electrical, and explained in Sec. **115**.

Detonators should be stored separately from other explosives, handled with great care and never left lying about. No attempt should be made to tamper with the fulminate of mercury.

3. **Commercial detonators.**—These are used commercially and are of various sizes and strength. A No. 8 commercial detonator is the same strength as a No. 8 service detonator, but it will not fit the service primer. In cases where No. 8 service detonators are not available, No. 6 commercial detonators should be used. These will fit the service primer, and, although of half the strength of the No. 8 service detonator, are sufficiently strong to fire a service primer.

4. **Primers.**—The few grains of fulminate composition contained in a detonator are not sufficient to detonate unaided wet gun-cotton and certain other stable high explosives. The detonating shock set up by the detonator, therefore, has to be amplified by a primer of explosive more sensitive than wet gun-cotton which acts as a medium of detonation between the detonator and the bulk explosive.

The service primer is made of dry gun-cotton.

5. **Dry gun-cotton.**—Dry gun-cotton is compressed nitro-cellulose without any additional water. It is very inflammable, burning with a fierce hot flame. If exposed to the sun's rays for a long period it may detonate spontaneously. Gun-cotton primers are issued in the form of 1-oz. tapered cylinders, provided with a hole in the centre for the reception of the detonator. The whole is coated with paraffin wax to keep it dry. The primers are packed in sealed tin cylinders, containing 10 primers.

6. **Fuze, instantaneous, detonating,** consists of a tin tube $\frac{5}{32}$-inch in diameter filled with high explosive (melinite or T.N.T.). To use the fuze it must be detonated; its action is practically instantaneous. It will not detonate if ignited.

The principal uses of fuze, instantaneous, detonating are :—

i. To fire a number of charges simultaneously when firing by safety fuze. It may sometimes be used in the same way in conjunction with electric firing to avoid complicated connections and circuits.

ii. To avoid the use of excessive lengths of safety fuze, which would otherwise be required in certain demolitions when firing by this method, *e.g.*, mined charges.

The method of detonating fuze, instantaneous, detonating, is shown on Plate **172**, Fig. 1; two primers and a No. 8 detonator with safety fuze are required.

The explosive in fuze, instantaneous, detonating, deteriorates on exposure to air; before using, therefore, about 6 inches of open end should be cut off. The ends of fuze, instantaneous, detonating, if they are likely to be left in charges for a long period, should be protected. A good method is to cap them with a No. 8 detonator.

Sharp bends in fuze, instantaneous, detonating, must be avoided as the continuity of the explosive is liable to be broken and failure result. The fuze must be carefully examined for this defect before use.

Junctions in fuze, instantaneous, detonating, may be made either by means of a primer—the incoming end is passed through the centre of the primer and the outgoing fuze or fuzes are lashed securely to the outside of the primer—or by using a junction box filled with ammonal into which the ends of the fuze are led; each should be capped with a No. 8 detonator.

114. *Making up and fixing charges.*

1. **General principles.**—In making up and fixing charges the following points are important:—

i. All portions of the charge must be in close contact with each other.
ii. The charge must cover the whole surface to be destroyed, and be in close contact with it.
iii. The charge as a whole must be firmly fixed to the object to be destroyed.

2. **Connecting up primer, detonator and fuze.**—i. The safety fuze is cut to the length required to give time to get to a place of safety after it is lighted. The end to be inserted in the detonator is cut straight across; the other end is cut on the slant to expose a larger surface for lighting.

ii. The straight cut end of the fuze is then carefully inserted in the open end of the detonator and pushed gently home so that the end of the fuze is in contact with the fulminate composition. The detonator should be held at the open end, and with the closed end pointing away from the body. The open end of the detonator is then gently pinched on to the fuze with a pair of pliers to make it grip and so prevent it being withdrawn. Care should be taken that no pressure is put on the closed end containing the fulminate.

iii. The primer should be tested to receive the detonator; if the hole in the primer is not large enough it must be enlarged by means of a "rectifier" (a wooden tool made for the purpose); if the hole is too large, paper must be wrapped round the detonator to make it fit firmly. On no account is force to be used to get the detonator into position; screwing or twisting it is particularly dangerous.

3. **Protection of charges.**—Charges exposed to the weather should be protected against damp and sun. General protection of a charge can be obtained by enveloping it in oiled silk or linen; alternatively, a board or a piece of tarpaulin cover can be used. To prevent damp reaching the detonator and primer, they should be completely enclosed in oiled silk and securely tied before insertion into the slab.

If instantaneous detonating fuze is used, it should be lashed at right angles to the No. 8 detonator outside the oiled silk, with a foot spare at the end.

If the charge is to be fired electrically, a No. 13 detonator, also enclosed in oiled silk, should be similarly lashed at right angles to the No. 8 detonator.

4. **Gun-cotton charges.**—A detonator with primer, buried in a concentrated charge, will detonate all explosives within a radius of 4 feet. In the case of an extended charge at least one point of detonation for each 10 feet run should be provided. Close contact between slabs is essential, and the primer must fit tightly into the tapered hole in the slab.

In making up gun-cotton charges for demolishing walls, arches, &c., it is often convenient to lash the slabs to a board which can be fixed firmly to the object to be destroyed. A hole is drilled in the board to enable the detonator to be inserted from the opposite side.

Timber packing and mud or clay are useful to secure close contact in fixing gun-cotton charges for the destruction of girders.

The "bag, gun-cotton, waterproof," which is an article of store, is used for demolitions under water or in damp places. It is a rubber bag with a wide mouth, provided with a wooden clamp for sealing it. The wooden clamp has two grooves cut in it, to permit electric leads or safety fuze being passed into the bag. Waterproof bags of this description holding 25 gun-cotton slabs or 25 lbs. of ammonal, form part of the equipment of engineer field units.

A gun-cotton slab can be detonated by fuze, instantaneous, detonating with the aid of a gun-cotton primer only, with which it must be in close contact A simple method of firing slabs with this fuze is that shown on Plate **172**, Fig. 2.

5. **Ammonal charges** may be fired by detonating:—

- i. A slab of gun-cotton fixed in close contact with a portion of the charge.
- ii. Two or three turns of fuze, instantaneous, detonating, wound round a tin of ammonal.
- iii. A detonator and primer buried in a portion of the charge. In the latter case, if the charge is in a damp place, a waterproof bag should be used as the container.

Ammonal re-acts chemically with copper and will gradually eat away the tube of a detonator, rendering its withdrawal after any length of time a dangerous operation. Method iii. should be used only when it is intended to fire the charge at once.

In emergency a detonator without primer is sufficient for the detonation of ammonal, but the explosive effect obtained is not so great.

In large charges ammonal may be left in the tins in which it is issued. The ammonal will detonate through the thin walls of the tins, provided the latter are packed in close contact.

For small charges ammonal may be placed in sandbags or waterproof bags. For rails and girder demolitions, preserved beef or tobacco tins often make suitable containers. Placing the charge in a tube of strong canvas is a good method for certain demolitions; the flexibility of the charge is its chief merit. For bore-holes stove-piping joined together, and if necessary waterproofed, makes an excellent container. A 6-inch pipe will take 10 lbs. to 11 lbs. of ammonal for each foot run.

6. **Dynamite charges.**—A gun-cotton primer is not required for the detonation of dynamite; a detonator or commercial cap is sufficient. The paper covering containing the cartridge is unfolded at one end and a hole, with a piece of wood the same size and shape as the detonator, made in the end of the cartridge. The fuzed detonator is then inserted in the hole and the end of the paper tied firmly round the fuze to hold the detonator in position (*see* Plate **174**, Fig. 4).

If dynamite requires ramming, as in a bore-hole, each cartridge should be squeezed gently into place with a wooden rammer, the fuzed cartridge being placed in last. The use of an iron bar for ramming is dangerous.

7. **Precautions in fixing detonators, &c.**—In making up charges, precautions must be taken to prevent any strain to which the fuze may be subjected being transferred to the detonator in the charge, since this might cause displacement and consequent failure, or the premature firing of the detonator. In the case of charges not requiring a container, the fuze should be fixed securely to the charge 3 or 4 inches from the detonator Where a bag container is used, a small piece of stick should be lashed at right angles to the fuzes just inside the bag. The fuze should be doubled back outside the bag, and lashed firmly to it (*see* Plate **174**, Figs. 2 and 3). Lengths of safety fuze leading to an exposed charge should be fixed lightly or weighted so that when lighted they may not curl up and set fire to the charge prematurely (*see* Plate **175**, Fig. 3).

The severe jerk set up in the instantaneous detonating fuze on detonation, tends to displace it; the fuze should therefore be secured firmly throughout its length especially to the charges it is to detonate. Lengths of instantaneous detonating fuze in contact or close to each other should be separated with a board, as one may cut the other without detonating it and cause failure.

8. **Lighting safety fuzes.**—The simplest method is to use matches; the match head should be held against the powder in the end of the fuze which has been cut on a slant, and ignited by striking the box on it.

Patent friction lighters may be used, but they easily get damp and are not therefore very reliable. They fit on to the fuze which in this case should be cut slant wise. If several fuzes have to be lighted in quick succession a port-fire may be used. It is an article of store and consists of a stick of slow-burning composition with a wooden handle. It can be lit with a match, and to be put out should be knocked against the heel of the boot. A cigar is a useful method of lighting charges. It should be brought to a sharp, clear point, free from ash; or a match-head should be pressed on the open composition, and the cigar or cigarette be applied to this.

9. **Mobile charges.**—Conditions do not always permit of the charge being made up on the spot, as for instance in a raid. Where detailed information of the objective is available, the form of the mobile charge may be adapted accordingly. Normally, however, the charge should be made up in box form of size and weight (not exceeding 20 lbs.) suitable for one man to carry without difficulty. It should be provided with a stout handle and two or more separate means of ignition by fuze. Patent lighters, being quicker to operate than matches, are a suitable means of

ignition for mobile charges, but matches or fuzees should be carried in addition in case of the failure of the former.

10. **Tamping.**—The tendency of all explosives is to act along the line of least resistance. Tamping is material placed round a charge in order to increase the explosive effect. Sandbags filled with earth are the material usually used for tamping. High explosives are so rapid in action that where they are in close contact with the objective, as in a rail or girder demolition, they accomplish their object without being enclosed on the exposed sides. Thus tamping in such cases, though it increases the effect, is not as a rule, necessary. On the other hand, in the case of mined charges tamping is essential as otherwise the main force of the explosion will pass down the gallery. The gallery in mined charges should therefore be tamped for a distance equal to twice the line of least resistance.

115. *Firing charges electrically.*

1. **General remarks.**—Charges on service are fired electrically by means of electric detonators, connected up by insulated cable, the usual source of energy being the service exploder.

In the following description of apparatus and methods employed, it is assumed that the theory of continuous current electricity is understood.

2. **The detonator, electric, No. 13, Mark III,** consists of a copper tube containing fulminate of mercury similar to the No. 8 detonator, but enlarged at its upper end to receive an ebonite plug. Two short copper leads, insulated with a rubber covering outside the detonator, are passed through this plug $\frac{1}{4}$ inch apart. The ends of the lead inside the detonator are connected together with a piece of fine iridio-platinum wire just above the fulminate of mercury. On a current of sufficient strength (not less than 0·8 amperes) being passed through the copper leads, the fine wire is raised to a white heat and fuzes, thus igniting the fulminate of mercury and causing it to detonate. The head of the detonator is painted white, and the tube containing the fulminate of mercury red. The detonators are packed in tin cylinders (25 detonators in each), the upper halves of which are painted white and the lower red. Detonators fired by an exploder must always be connected up in series in a circuit. The electrical resistance of a No. 13 detonator at fuzing point is 2·6 ohms.

3. **Insulated cables.**—Any insulated cable may be used provided its electrical resistance is not too great. The cable especially designed for demolitions in the field and normally available on service is the cable electric E_1, Mark II. It consists of 6 copper and 1 steel strand covered with vulcanized india-rubber and coated with compound. It is issued wound on wooden drums. The electrical resistance of the E_1, Mark II cable is 1·31 ohms. a 100 yards.

4. **The Exploder, Dynamo, Electric, Mark V** is contained in a wooden box 13 by 8 by 6 inches, painted white and fitted with a lid which can be locked It consists of a dynamo operated by a handle, which converts mechanical energy into electrical energy. It is fully described in Military Engineering, Vol. IV.

To use the exploder, the handle is pulled up as far as it will go, and the leads of the circuit connected to the exploder terminals. The downstroke of the handle turns the dynamo and thus generates a current, which is at its maximum at the bottom of the stroke, when it flows through the leads. The handle of the exploder should be forced down as swiftly and smoothly as possible.

If in a good condition a Mark V exploder will fire No. 13 detonators in a circuit the total resistance of which (including that of the detonators) is 100 ohms. Where, however, an exploder has not been tested to ascertain the actual resistance through which it will fire, it is unsafe to rely upon it for a circuit of more than 40 ohms resistance. This figure is given in order to allow a good margin of safety for any defects in the working of the exploder.

Detailed tests for exploders are given in Military Engineering, Vol. IV.

The approximate resistance of a circuit can be estimated by adding the total cable resistance (1·31 ohms a 100 yards of E_1, Mark II cable) to the total resistance of the detonators at fuzing point (2·6 ohms for each detonator). If the resistance of the circuit thus ascertained is beyond the power of the exploder, it must be reduced by using fewer detonators, duplicate cables, or cables of lower resistance, or by using Fuze I.D. to connect the charges.

To ascertain roughly if an exploder is in working order a No. 13 detonator should be connected up to the terminals and fired. The detonators should be placed in an iron box or under a sod so that they may do no harm when fired.

5. **Jointing insulated cables.**—The jointing of insulated cables is a most important operation, since a badly made joint may be the cause of failure. It should be carried out as follows :—Strip off 2 inches of the insulation of each cable, open out the stranded wires and clean each thoroughly by scraping with the back of a knife; take great care not to nick the wires in doing this. Cross the ends of the cables thus cleaned at right angles as shown on Plate 177, Fig. 1, and bend them round each other as shown on Plate 177, Figs. 2 and 3, making three or four complete and close turns with each end. Cut off the spare ends and pinch them close in with the pliers. Now cut off about 6 inches of india-rubber tape and warm it by rubbing it between the hands. Then bind the rubber tape round the joint (as on Plate 177, Fig. 4). The tape should be stretched as it is applied. When the joint has been covered with one layer of tape, the rubber should be smeared with rubber solution and the tape wrapped on in successive layers until used up, each layer being smeared with rubber solution. No solution should be allowed to reach the bare wires of the cable.

Defects in the insulation of cables may be dealt with in a similar manner. Rubber tape and solution form part of the contents of the boxes testing and jointing carried by engineer field units.

6. **Testing circuits.**—The continuity test is normally sufficient except for very important charges. It consists in sending a small current through the circuit not large enough to fire the detonators but sufficient to deflect the needle of a detector or galvanometer placed in the circuit, thus proving that the electrical circuit is unbroken. A special test cell (cell, electric, dry, E) is used to furnish the current, and is so constructed that it can under no conditions give sufficient current to fire a detonator. The use of any other type of cell, furnishing a larger current than a test cell is highly dangerous. A test cell and a 3-coil galvanometer are provided in the "Box testing and

jointing"; they should be connected up in series to the ends of the circuit to be tested. The "I" coil of the galvanometer should be used in testing for continuity.

In all important work the detonators and cables should be tested separately for continuity before being connected up as well as the whole circuit when laid.

Detailed tests for electric firing circuits are given in Military Engineering, Vol. IV.

7. **Connecting up and firing charges electrically.**—The following, therefore, are the steps to be taken:—

i. The cables, having been tested for continuity, are laid out from the charge to the selected firing point. The ends of the cables at the firing point should be placed in charge of an N.C.O. and the exploder box kept locked.

ii. The cable ends at the charge are now connected up to the detonator leads.

iii. The detonator, previously tested for continuity, is placed in the charge. The precautions laid down in Sec. **114**, 2, as to fitting the detonator into a primer must be observed.

iv. The whole circuit is now tested for continuity as described in para. 6 above.

v. The exploder box is unlocked; the handle raised and the ends of the cables made fast to the exploder terminals.

vi. To fire the charge the handle is pushed down swiftly and smoothly. Where several charges are to be fired simultaneously the procedure is similar. The detonators are connected up in series by lengths of cable as required.

Diagrams of circuits for testing and firing are shown on Plate **177**, Figs. 5 and 6.

8. **Common causes of failure.**

i. Broken leads.—The leads used in demolitions carried out in the presence of the enemy should, if possible, be buried. Two feet of earth is adequate protection against bullets and small shell splinters, and 7 feet from shell fire. The cables should not be subjected to undue strain at any part of the circuit. Special care should be taken where they pass through the tamping or round corners.

ii. Badly-made joint, causing a high resistance and thus preventing sufficient current flowing through the circuit to fire the detonators.

iii. Bad insulation of cable or joints, causing leakage of current.

iv. Faulty exploder.

v. Defective detonator. The iridio-platinum wire may be broken. This, however, would be detected by the continuity test. Detonators may also be over- or under-sensitive (*see* Military Engineering, Vol. IV). The No. 13 detonator is, however, carefully tested before issue and is most reliable.

116. *Alternative methods of firing.*

1. The chief merit of safety fuze as a method of firing is its simplicity and the fact that, once the charge is laid, no apparatus other than a box of matches is necessary to fire it.

The electrical method, however, enables the charge to be fired from a distance and at the precise instant desired, while at the same time it is admirably suited for the simultaneous firing of multiple charges. Moreover, the facility with which an electric circuit can be tested, at a distance from the charge it is to fire, is an added advantage, especially where the charge is not easily accessible for examination. On the other hand electric leads are very liable to be cut by shell fire; they may be protected by burying them, but this entails considerable labour—to be reasonably safe from damage, 7 feet of earth is necessary.

Thus the selection of the safety fuze or electrical method will depend on the conditions. Electric firing is undoubtedly the surer method in deliberate demolitions provided the danger of the leads being cut is remote and that it is carried out under the direction of an individual who understands it. On the other hand in hasty demolitions firing by safety fuze owing to its simplicity is, as a rule, the more suitable method. For instance, mobile charges will almost invariably be fired with safety fuze, while it is usually preferable to fire mined charges electrically. Whichever method is adopted all important charges should be provided with at least two means of ignition. In many cases a good plan is to use both methods, using the safety fuze as a stand-by in case of the breakdown of the electrical firing arrangements.

2. **Common causes of failure.**—i. The charge may have become too damp to detonate. Even gun-cotton slabs, if exposed to damp for a long period, may fail. Cases have occurred where owing to the deterioration of the paraffin wax covering primers, the dry gun-cotton has absorbed moisture from the wet gun-cotton slab surrounding it and failed to detonate.

ii. The charge may not entirely cover the object to be destroyed or has not been placed in close contact with it.

iii. There may not be close contact between the bulk explosive and primer, primer and detonator or detonator and fuze. The precautions laid down in Sec. **114**, 1 and 2, should be carefully adhered to.

iv. The fuze may have deteriorated through dampness or age and become unreliable.

v. Failures from electrical firing are dealt with in Sec. **115**, 8.

vi. In firing charges in the presence of the enemy, men should be detailed to replace casualties, in order that failure may not result from this cause.

3. **Miss-fires.**—If a miss-fire occurs the longest possible time should be allowed to elapse (at least half an hour) before the charge is approached. In accessible places, the charge should be "killed" by detonating a fresh charge as close as possible to it. The charge should only be withdrawn when there is no alternative, as its removal will be a dangerous operation. In such cases, the tamping in proximity to detonators must be carefully removed, the whole being previously drenched with water, and the detonators withdrawn at the earliest opportunity.

117. *Demolitions—general principles.*

1. The main uses of demolitions in warfare are:—

i. To delay the advance of an enemy by the destruction of communications over which he must pass or material which will fall into his hands (defensive)

ii. Impairing an enemy's resistance by the destruction of captured communications which cannot be permanently held or materials that cannot be removed, as, for instance, in a raid (offensive).

iii. Destruction of obstacles to facilitate the advance of our own troops (offensive).

2. The following points should be considered when selecting objectives for demolition:—i. The execution of a few complete demolitions at points in communications where there is no alternative route will delay the enemy more than a number of demolitions each of which can be quickly repaired or circumvented.

ii. Subject to the conditions stated in i. the following are the most suitable points of attack on communications (roads and railways):—

(*a*) Bridges, culverts and tunnels.
(*b*) Cuttings and embankments.
(*c*) Road and railway junctions, level crossings and cross roads.
(*d*) Causeways passing over low-lying or marshy ground.

iii. The possibility of effecting destruction by means other than explosive should not be overlooked. This is especially important where the explosive available is limited, as, for instance, in a raid. Wooden bridges and stores may be burnt, certain materials rendered unserviceable with water, machinery disabled with crowbars or by the removal of indispensable parts, &c.

3. **Reconnaissance.**—The importance of thorough reconnaissance in all demolitions cannot be over-estimated. Haphazard and promiscuous methods without a clearly-defined plan cannot produce good results. Whenever demolitions are to be carried out on an extensive scale, a comprehensive and well-considered scheme should be drawn up, in which due weight is given to both tactical and technical features. Individual objectives should invariably, in so far as conditions permit, be carefully examined before the details of the method of destruction to be employed are decided on.

4. The extent to which demolitions are to be carried out in an operation will be laid down by the higher command. The responsibility for ordering demolitions should be delegated to commanders of infantry brigades or other formations whose units are in contact with the enemy. Officers (or N.C.Os.) in charge of demolition parties must be told who will give the actual order as to when the charge is to be fired (*see* Sec. **110**, 9, F.S.R., Vol. II, 1924).

5. **Deliberate and hasty demolitions.**—To effect the complete demolition of a structure requires careful reconnaissance, ample time for the preparation of charges, and conditions which will permit of the fixing and firing the latter without serious enemy opposition. Where these conditions do not prevail, procedure on these deliberate lines cannot be carried out. It will then, as a rule, only be possible to aim at effecting partial destruction; the most rapid and easily-executed method of attack having to be adopted in preference to that which will cause the most damage.

Demolitions may therefore be classified broadly under the headings of "deliberate" and "hasty." For example, the destruction of one or both abutments by mined charges is normally the most important operation in the deliberate demolition of a girder bridge, while time would only permit of the destruction of the main girders in the case of a hasty demolition. It must be borne in mind, however, that the quantity of explosives available may also prove a limiting factor as to the method of destruction adopted, the problem presented being in all cases that of effecting the maximum damage to the objective in the time available, and with the means at disposal.

118. *Calculation of charges.*

1. The weight of explosive (untamped) in pounds required for various demolitions can be calculated from the formulæ in the following table. They are equally applicable to gun-cotton or dynamite; if ammonal is used, they must be doubled. In these formulæ:—

B = length to be demolished in feet.
T = thickness to be demolished in feet.
t = thickness to be demolished in inches, in the case of steel or iron plate only.

Object attacked.	Lbs.	Remarks.
Masonry arch, haunch or crown ...	$\frac{3}{4}$ B.T^2	Continuous charge.
Masonry pier	$\frac{5}{8}$ B.T^2	
Masonry wall over 2 feet thick ...	$\frac{1}{2}$ B.T^2	Continuous charge. The length of breach B not to be less than the height of wall to be brought down. Walls under 2 feet thick require 2 lbs. a foot run.
Hard wood (rectangular section) ...	3 B.T^2	For soft woods these charges may be halved.
Hard wood (circular section)	3 T^3	
Hard wood, auger hole...	$\frac{3}{8}$ T^2	
Iron or stee lplate	$\frac{3}{2}$ B.t^2	t is in inches. (N.B.—A slab of gun-cotton will cut a steel plate 1 inch thick.)
Reinforced concrete	5 to 20 B.T^2	According to amount of reinforcement. Major portion of charge placed where reinforcement is heaviest (*i.e.*, on lower flange in case of girders).
Steel wire cable 4 inches in circumference and over.	$\frac{C^2}{16}$	C is circumference in inches. Cables under 4 inches in circumference require 1 lb. to cut them.

Masonry includes concrete, stone or brickwork. Tamping will increase the effect of the above charges. Charges placed hurriedly under conditions, where they cannot be examined properly after being fixed, should be increased by a percentage (say 50 per cent.) to allow for bad contact, &c.

2. **Mined charges.**—The method of calculation of mined charges to produce craters of varying diameters in different soils is laid down in Military Engineering, Vol. IV. The following table, however, gives the weight of ammonal or similar high explosive required in hard chalk. For ordinary demolitions it will be found sufficiently accurate for use in all soils; in softer ground larger craters will be made.

Ammonal charge in lbs.

Depth to centre of charge in feet.	Diameter of crater.					
	30 feet.	40 feet.	50 feet.	60 feet.	70 feet.	80 feet.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5 feet	160	360	—	—	—	—
10 feet	170	390	750	1,260	1,950	2,900
15 feet	190	420	800	1,350	2,050	3,000
20 feet	210	460	850	1,400	2,150	3,100
25 feet	—	490	900	1,470	2,250	3,250
30 feet	—	—	1,000	1,500	2,350	3,400

The formation of craters by means of mined charges makes a formidable obstacle in roads and railways, especially where deviation is difficult. For mined charges, however, explosives in considerable quantities must be available and their preparation entails the expenditure of much time and labour. They are thus essentially deliberate demolitions. The ruling principle as to the selection of points of attack is laid down in Sec. **117,** 2. The charge should be placed under the centre of the road or railway, and should be calculated to form a crater large enough to remove the whole width of the permanent way or metalled surface. The deeper the charge, provided adequate quantities of explosive are available, the greater will be the effect attainable. In many cases, however, the depth may be limited by the presence of water. To lay the mine a vertical shaft is sunk at the side of the road, and a horizontal or inclined gallery driven from the bottom of the shaft to the required depth under the centre of the road, where a chamber for the reception of the charge is constructed. It is best to place the chamber on one side of the gallery to increase the tamping effect. It should be of dimensions to correspond with the charge calculated. The charge is then laid and prepared for firing and the horizontal gallery tamped with sandbags. Where the charge is to be placed in an embankment the digging of a shaft is not as a rule necessary, a horizontal or inclined gallery being driven from the surface to the required position for the charge. In some cases, the cellar of a house at the side of a road may form a convenient point from which to drive a gallery. The method of constructing shafts and galleries and of laying mined charges is given in detail in Military Engineering, Vol. IV.

The priming charges containing the detonators should be placed in waterproof bags, even in apparently dry soils, whenever the mined charge is to be left in position for any length of time. In marshy or water-logged soils it is often not practicable to lay mined charges, owing to the difficulties presented in constructing the shaft and gallery and of keeping the charge waterproof.

In such cases waterproofed metal tubes filled with ammonal (as described in Sec. **114,** 5) may be fired in bore-holes made with earth augers or borers. This method is, however, not so effective as a mined charge.

119. *Demolition of iron and steel work.*

1. As gun-cotton is the most suitable explosive for such demolitions, its use only is considered, but the principles laid down will apply where other high explosives are used.

The formula $\frac{3}{2}$ B.t^2 should be used in calculating all charges for iron and steel work. The charge must extend along the whole breadth of the material to be cut. It thus follows that the minimum charge of gun-cotton is one slab for every 6 inches of breadth to be cut. It is useful to remember that by the formula a slab of gun-cotton will cut metal 1 inch thick, one slab of gun-cotton will cut a first class steel rail. (Plate **175**, Fig. 3.)

In carrying out the destruction of metallic substances (guns, girders, rails, &c.) it should be remembered that fragments are liable to be blown 1,000 yards or more away from the spot where the demolition is being carried out.

2. **Girders.**—There are so many different forms of girders in use that it is impossible to lay down rules for their destruction which shall be applicable to all. The engineer must be prepared to use his own judgment.

In demolishing girders there is, as a rule, difficulty in obtaining proper contact between the charge and the metal owing to the presence of rivet heads. The best method of meeting this difficulty is to fill the spaces between the rivet heads with clay and include the depth of this layer in the thickness to be cut.

All girders are made up of a top and bottom "flange" connected by a "web" consisting of continuous plates in plate girders or of open cross bracing in braced girders.

With plate girders, the most economical method of destruction is to place continuous charges across the top and bottom flanges and the web. The weight of the charges, sufficient to cut through the metal in each case, is calculated from the formula $\frac{3}{2}$ B.t^2. This method, however, involves the simultaneous firing of three separate charges, moreover, difficulties in fixing them to the girder may often arise. Normally, therefore, the best method of destruction of ordinary plate girders is that shown on Plate **173**, Fig. 1. Separate charges are calculated for the top and bottom flanges and the web.

Plate **173**, Figs. 1 and 2, and Plate **174**, Fig. 1, show three different methods of fixing charges to a girder. Circumstances will determine which is the best in each case.

In calculating the charge for the web, only that portion between the angle irons is considered, as allowance is made in the flange charges for the destruction of that portion of the web which is thickened at the junction with the flanges. If the web does not exceed 1 inch in thickness, one slab for each 6-inch length to be cut is necessary. Where the thickness exceeds one inch, the charge must be calculated from the formula, $\frac{3}{2}$ B.t^2. For the flanges the charge is calculated from the formula, t is taken as the maximum thickness of flange plus rivet head and B as breadth of flange in feet. To allow for the fact that the charge is not placed continuously along the flange and for the additional explosive required to cut the thick portion of the web at the junction with the flange, the charge arrived at from the formula must be doubled.

Example: Girder, Plate 173, Fig. 1.

i. *Web.*—Thickness of web = $\frac{3}{8}$ inch, *i.e.*, under 1 inch.
Therefore one slab for every 6 inches will suffice.
Length of web between angle irons = 27 inches.
∴ No. of slabs required for web = 5.

ii. *Top flange.*—Maximum thickness $t = \frac{1}{2}$ in. (flange) + $\frac{1}{2}$ in. (angle iron) + $\frac{1}{2}$ in. (rivet head) = $1\frac{1}{2}$ ins.

$$\text{Breadth B} = \frac{15}{12} \text{ feet.}$$

$$\therefore \frac{3}{2}\text{B}.t^2 = \frac{3}{2} \times \frac{15}{12} \times \left(\frac{3}{2}\right)^2 = 4\cdot2 \text{ lbs.}$$

∴ Charge required = 8·4 lbs. or 9 slabs.

iii. *Bottom flange.*—Maximum thickness $t = \frac{1}{2}$ in. (flange) + $\frac{5}{8}$ in. (angle iron) + $\frac{1}{2}$ in. (rivet head) = $1\frac{5}{8}$ ins.

$$\text{Breadth B} = \frac{15}{12} \text{ feet.}$$

$$\therefore \frac{3}{2}\text{B}.t^2 = \frac{3}{2} \times \frac{15}{12} \times \left(\frac{13}{8}\right)^2 = 5 \text{ lbs.}$$

∴ Charge required will be 10 lbs. or 10 slabs.

In the case of braced girders a suitable point along the girder must be selected at which to cut through all the members. Charges must then be calculated separately from the formula for each member, *i.e.*, top and bottom flanges and the web bracing.

3. **Hasty demolition of railway girder bridges.**—For hasty demolition of railway girder bridges when there is not time to measure the section of the girder, the following formula will give sufficiently accurate results within the limits stated :—

$$\text{C} = \frac{\text{L}^2}{15\text{D}}$$

where C = charge of gun-cotton in slabs (1 lb.) including the allowance of 50 per cent. for the presence of the enemy.

L = length of girder in feet.
D = total depth of girder in feet.

This formula gives the charge required for one girder of single line of standard railway. The charge must be placed near an abutment and be divided up and fixed to the girder in the manner described above.

The formula is applicable to girders of spans varying from 20 feet to 80 feet. Where one girder has to bear the whole load of a line of railway, *e.g.*, two girders carrying a double line, or a centre girder carrying half of two single lines, the amount given by the formula should be doubled. This will, however, give rather more than the necessary charge.

4. **Guns.**—To destroy a gun with high explosives a shell should be loaded in the ordinary way; the charge necessary for the destruction of the gun

should be packed behind it so as to be in close contact with the shell and with the sides of the chamber.

After the insertion of the firing arrangements the charge should be tamped with earth or other suitable material to keep it in position.

The breech should be closed as far as possible, just allowing room for the safety fuze or electric leads for firing the charge. A shell is not absolutely necessary for destroying a gun by this method, but increases the effect. The charge required is calculated by the following rule:—" For a 3-inch gun use 2 lbs. and double the charge for every inch increase in calibre, *e.g.*, for a 4-inch gun use 4 lbs., and for a 5-inch gun, 8 lbs."

If explosive in bulk is not available, a gun may be destroyed by placing a high explosive shell in the breech and detonating it, after first blocking the bore.

Destruction may also be carried out by placing an obstruction in the bore in such a position as will ensure it being struck by the fuze of a suitably fuzed H.E. shell when fired. A reversed H.E. shell, suitably fuzed, placed in the muzzle will suffice.

The gun may be fired by means of a long lanyard from under cover. A length of telephone cable attached to the firing lanyard is suitable for this purpose.

120. *Demolition of buildings, stockades, &c.*

1. **Buildings.**—Buildings are best demolished by placing charges of explosive in the interior, preferably in the angle of the main supporting walls on the ground floor. All windows, doors and chimneys should be closed. For small brick houses and cottages charges of 10 lbs. a room will generally be sufficient and for more solidly built houses 20 lbs. a room. The charges should, if possible, be fired simultaneously. For large halls, theatres, &c., and buildings of exceptionally solid construction the demolition in detail of the main walls may often be the most effective method of destruction. When demolishing houses with cellars the charge should be placed in the cellar, as otherwise the enemy is presented with a ready made dug-out.

For hollow towers such as are found on the North-West Frontier of India and other countries, the number of pounds of gun-cotton is given by the diameter of the tower in feet plus four. This charge should be buried in the base of the tower.

2. **Stockades.**—The charge of high explosive required to effect a breach in a stockade may be calculated roughly from the following data:—

Stockade of earth between timber up to 3 feet 6 inches thick requires 4 lbs. a foot run of breach. A heavy rail stockade requires 7 lbs. a foot run of breach.

3. **Barbed-wire entanglement.**—For cutting a passage through a barbed wire entanglement in hasty demolitions, a form of mobile charge, known as a Bangalore torpedo, may be used. It consists of an iron pipe, or one made of stout zinc or tin plate, filled with ammonal. The fuzed detonator and primer are inserted at one end. The pipe is closed at its extremities with wooden plugs, through one of which a hole is made for the safety fuze. The pipe should be laid on the strands of barbed wire and should be at least 2 inches in diameter if a clear passage is to be cut. With Bangalore torpedoes

over 10 feet long, a piece of instantaneous detonating fuze should be run through the length of the charge to ensure detonation throughout.

4. **Timber posts, trees, &c.**—The most economical method of destroying posts, trees, &c., with explosive is by making an auger hole to just beyond the centre for the reception of the charge which is calculated from the formula $\frac{3}{8}T^2$.

Piles which are to be cut off under water at their base are best dealt with in the following manner. The waterproofed charge is attached to the pile above the water by a piece of wire rope, wound round the pile sufficiently loose so that the whole will slide down the pile. A stick up which the fuze or leads are lead is attached to the rope ring, and the charge is pushed down in position below the water-level to where the pile enters the ground.

121. *Demolition of bridges.*

1. **Deliberate.**—Provided an adequate supply of explosives is available, the deliberate demolition of a bridge will involve the destruction of the following:—

- (*a*) One or both abutments.
- (*b*) The intervening piers (if any).
- (*c*) The main girders.

(*a*) *Abutments.*—If the abutments of a bridge are destroyed, the difficulty of repairing it is much increased. Thus their destruction is normally the most important operation in deliberate bridge demolitions, especially when no deviation is possible.

The usual method adopted is the laying of a mined charge as described in Sec. **118**, 2, sufficiently close to the abutment to blow it down, at the same time as the crater is formed. The most suitable position and the weight of the charge will be governed by the strength of the abutment walls and other conditions. The following rules, however, will be found to work well in most cases (*see* Plate **174**, Fig. 5).

- i. If "b" is the breadth of the abutment, the charge should be placed in the centre of the abutment at a distance "e" from the outside face of the abutment equal to $\frac{1}{2}$ "b."
- ii. The depth of the charge "h" should be between $1\frac{1}{4}$ and $1\frac{1}{2}$ times "e" and in the case of masonry bridges at least as deep as the springing of the arch at the abutment.
- iii. The weight of the charge may be calculated from the table given in Sec. **118**, 2, but in this case the depth of centre of charge is taken as "e," and the diameter of crater desired as "b." If ample supplies of explosive are available, the charge thus calculated may be increased with advantage up to 100 per cent. in order to produce a greater range of disruptive effect on the abutment foundations.

Example.—It is required to destroy the bridge shown on Plate **174**, Fig 5, which is 28 feet wide:—

$\therefore$ b = 28 feet.
and e = 14 feet.

Depth of centre of charge—
= $1\frac{1}{4}$ to $1\frac{1}{2}$ times 14 feet.
= $17\frac{1}{2}$ to 21 feet (say 20 feet).

From table of charges Sec. **118**, 2, a crater of 30 feet diameter (b = 28 feet) is produced at a depth of 15 feet (e = 14 feet) by a charge of 190 lbs. A suitable charge (increasing by 100 per cent.) would therefore be 380 lbs.

(*b*) *Piers.*—These are best destroyed by a series of mined charges placed either in boreholes or chambers excavated from the side (*see* Sec. **47**, 1 and Sec. **49**, 6, Military Engineering, Vol. IV, 1923).

If time does not permit of this method, a cutting charge calculated from the formula given in Sec. **118**, 1, should be placed along one face of the pier. Where, however, the thickness of masonry exceeds 5 to 6 feet, the employment of a cutting charge becomes unreliable and extravagant in explosive.

(*c*) *Girders.*—The main girders will be brought down by the destruction of the abutments and piers, but it is important to ensure that they are sufficiently damaged to render them useless for re-erection. They should therefore be cut with explosive charges as described in Sec. **119**, 2.

2. In carrying out all bridge demolitions it should be borne in mind that the destruction of the approaches to a bridge by means of mined charges may often be as important as the destruction of the bridge itself.

3. Light wooden trestle bridges with timbers up to 9 inches by 3 inches may be burnt by using petrol or tar. Heavy wooden bridges with timber of larger dimensions should be destroyed with explosives.

4. **Hasty.**—In hasty demolitions the destruction of the girders or arches of a bridge is, as a rule, all that can be attempted, while occasionally conditions may permit of more extensive damage being effected by the destruction of one or more piers.

The arches of a masonry bridge may be attacked at the haunches or the crown. The former method is much to be preferred as a larger gap will be made, but more explosive will be required than for a single charge placed at the crown. The charge may be calculated from the formula given in Sec. **118**, 1. If time and conditions permit a trench should be dug across the roadway down to the masonry of the arch, for the reception of the charge, which should be continuous and in close contact with the masonry (*see* Plate **174**, Fig. 5). The trench should be filled in after the charge has been laid as this tamping will increase its effect. When conditions do not permit of a trench being dug, the charge may be fixed to a board as described in Sec. **114**, 4, and the whole secured firmly to the under side of the arch so that the charge is in close contact with it throughout the whole width of the bridge. The board must be firmly strutted up from below ; sufficiently good contact cannot be obtained by trussing.

Although time, when the demolition is a hasty one, will never permit of the destruction of bridge abutments by heavy mined charges, on the lines stated in para. 1 above, it may be possible under certain conditions to damage them considerably. The main difficulty is to obtain a hole in or behind the abutment in which to place the charge. This may sometimes be overcome by blowing a small initial charge, up to 50 lbs., to form a cavity for the main charge. Although the whole operation is thus performed in two stages, it need not take more than half an hour to carry out if the charges can be prepared beforehand. Another method, specially suitable where the approach is an embankment, is to make one or more bore-holes with an earth-auger behind the abutment masonry and to load the holes with ammonal in stove-pipes (*see* Sec. **114**, 5).

122. *Demolition of railways.*

1. The destruction of railway bridges and the blowing of craters at selected points in the permanent way have already been dealt with in Secs. **117, 118** and **121.** Tunnels may be destroyed by placing mined charges in the roof or walls. Ventilating shafts often form a suitable chamber for such charges. An alternative method of destruction requiring less explosive is to demolish a length of the arch-ring, the charge required being the same as that for destroying the arch of a bridge. Where the destruction of the tunnel is not desirable, an effective obstruction may be made by causing the derailment or collision of rolling stock in it; the removal of the wreckage within the cramped space of a tunnel is a difficult and lengthy proceeding.

Much damage to the permanent way, rolling stock and appliances of a railway can be effected without explosives. The method of attack must depend largely on the time at the disposal of the working party, its numerical strength and on the extent of the damage it is desired to carry out.

2. When a railway is to be interrupted, the first step in every case is to sever or block the main lines of rails. As soon as this has been done, points and crossings, as being the most important parts of the permanent way, should be destroyed or removed (Plate **175**). The water supply should then be rendered useless. Pumps and tanks should be destroyed either with explosives or by knocking off rivets, &c., with a sledge hammer and so causing leakage. All signals, both electric and visual, should be destroyed.

Station buildings, as a rule, are not indispensable to traffic and, therefore, not worth destroying; but workshops and repair shops should, if possible, be burnt out and their fittings and machinery and all other technical tools or apparatus removed or destroyed. Fuel should be removed or burnt. If rolling stock cannot be removed it can be rendered useless by burning, or trains may be derailed, preferably over an embankment or in a tunnel by turning a rail.

3. The simplest method of attacking the permanent way is to remove or destroy portions of the line or lines at intervals, especially curves. If sufficient explosive is available, destruction may be effected by firing a charge of two slabs at each rail joint (Plate **176**). This spoils the fish plates and bolts, and either cuts or bends each rail. With steel sleepers a good method is to dig down in the centre of the track underneath a mid-rail sleeper and to place two slabs in the hole but not in contact with the sleeper. The excavated ballast should be packed in as tamping. The expansion of air buckles the sleeper and draws the rails together, at the same time twisting them outwards.

Permanent way may be destroyed without explosive by disconnecting two opposite joints and overturning the track. It requires 30 men to start this process, but once started, the spring of the rails will assist, and it can be continued with rapidity by a small party.

Rails can also be damaged by making fires with wooden sleepers, placing the rails upon them and twisting them when hot. If the rails are only bent, they can be straightened on the spot, but if twisted they must be sent to the mill to be re-rolled before they can be used again. To remove the rails the fish plate nuts should be unscrewed with a spanner : if one is not available they can generally be broken off with a hammer. The chairs should be broken off with a sledge hammer. If time and conditions permit the permanent way may be taken up and removed bodily in trains, but this requires careful organization and large working parties and should be left to railway experts.

4. When it is desired only to disable rolling stock or instruments the guiding principle should be to destroy or remove the whole supply of one article essential to the working of the railway rather than to effect promiscuous but incomplete damage of several things. The adoption of this course of action prevents a few complete units being formed from the parts of damaged ones. Locomotives can be rendered useless but still repairable by taking off the injector, the connecting rods, piston or valve; carriages can be similarly disabled by removing the springs so as to let the body of the carriage fall on the wheels and axle.

CHAPTER XVII

LAND MINES, TRAPS, &c.

123. *Types of mines and traps.*

1. **Land mines** are explosive charges laid in the ground with the object of delaying the advance of an enemy, by impairing his morale, destroying his personnel and transport, and interrupting his communications after the evacuated ground has fallen into his hands.

The quantity of explosive used will depend upon the purpose for which the land mine is laid and may vary from a few pounds to several hundreds. High explosive shells and trench mortar bombs may often be suitably used for the charge in place of bulk high explosive.

Land mines may be divided into three classes according to the method by which they are set in operation.

i. Contact.
ii. Observation.
iii. Delay action.

i. **Contact mines.**—These normally consist of a small charge of explosive buried a few inches below the surface of the ground and contained in a specially designed box, or a shell, fitted with some form of contact firing arrangement. The latter is so constructed that pressure on the surface of the ground caused by troops or vehicles passing over it, sets it in operation and fires the charge. This firing arrangement in most forms functions by percussion or friction, the release of a striker firing a percussion cap (just as a cartridge is fired in a gun) or igniting friction composition. In some types, however, it may operate electrically, the pressure on the surface closing a circuit and thus firing the charge.

The designs of contact mines which may be met with are very numerous. A few representative types are described in Military Engineering, Vol. IV. Extensive fields or belts of such mines may be laid and there is much scope for the skilful selection of sites where traffic is likely to pass and yet where the detection of mines is difficult. The mines should be so spaced as to render it practically impossible for a wheeled vehicle or tank to pass through the belt without exploding one of them.

It is, as a rule, difficult to conceal contact mines in the metalled surface of roads. They may sometimes be placed with advantage on the edge of roads where traffic is still likely to pass and where the surface is, as a rule, more muddy and thus affords greater facilities for concealment. A ruse often adopted is to place an obstacle in the road and to lay a minefield on each side of it where a deviation would normally take place. A crater forms a specially satisfactory obstacle in such cases, as the debris scattered round it from its explosion serves to obliterate any traces on the surface of the existence of a minefield.

ii. **Observation mines** are land mines which can be fired by electricity from a distance when the enemy is seen to pass over them. They may be laid in front of a defended position in ground over which the enemy is likely to advance or mass for attack. Their use, however, as compared with contact mines is rather limited.

A fougasse which is a special form of this type of mine is shown in Plate 176. A low explosive must be used for the charge, the arrangement being an improvised form of mortar. An excavation is made as shown, the spoil being placed on the rear edge to reduce the likelihood of the explosive breaking out in this direction. The charge is then placed in the recess at the bottom and covered with a platform of boards from 3 to 4 inches thick, on which the stones or other missiles are piled. The axis of the hole should be inclined at about 40 degrees to the horizontal, the sides being inclined at about 12 degrees to the axis.

A fougasse of the form shown charged with 80 lbs. of gunpowder should throw 5 tons of bricks and stones over a surface of about 160 yards long by 120 yards wide.

Fougasses are difficult to conceal and therefore advantage should be taken of bushes, undergrowth and broken ground. They may sometimes be fired automatically by a contact device instead of by observation.

iii. **Delay action mines** are operated by a delay action fuze, by means of which the time of the explosion, after the charge has been laid, may be deferred for a period varying from a few hours to several weeks or even months. The simplest and most satisfactory type of delay action fuze hitherto invented depends on the dissolving of a fine steel wire by a corrosive liquid; the length of the delay is regulated by varying the strength of the liquid. It is fully described in Military Engineering, Vol. IV, 1923.

Delay action mines will, as a rule, consist of charges of several hundred pounds laid at depths suitable to form large craters. They are specially suitable for laying in the permanent way of railway lines, bridge abutments, &c., with a view to causing intermittent interruption of road and rail communications, after the damage effected by ordinary demolitions prior to the retreat has been repaired by the enemy. They may also be laid with success in billets, dug-outs, &c., which the enemy is likely to occupy, and in abandoned shell dumps. In the latter case difficulty of detection may be increased by the container of the delay action fuze being constructed to resemble an ordinary shell fuze.

2. **Traps.**—Improvised contact mines and charges, placed with the object of making the occupation of dug-outs, buildings, &c., dangerous, when abandoned to the enemy are commonly known as "traps." They are not, as a rule, very destructive to personnel, but the atmosphere of uncertainty they produce has a considerable moral effect on advancing troops and may deter them from using much valuable shelter.

In principle their method of working is similar to land contact mines. The design of traps must be adapted to suit the local features of each particular case, and in general the more varied their form the more difficult will be their detection. There is ample field for ingenuity and cunning in constructing these devices.

The following are a few typical instances of traps which may be laid:— A loosened board so arranged that a charge is fired on the former being stepped on. An attractive souvenir or trinket so attached to a concealed charge that it fires the latter on being moved. A charge placed in a chimney so that an explosion occurs as soon as a fire is lighted. Charges may be so made up that they are fired on the following actions:—the opening of a door, window, cupboard or drawer; switching on electric light, pulling the plug of a water-closet, cutting or tripping over a wire.

3. **General remarks.**—The making and laying of all land mines and traps is a dangerous operation, and should be carried out by experts. Wherever they are to be used on an extensive scale a considered scheme is essential; careful records should be kept of the position and nature of all mines and traps laid.

124. *The detection of land mines and traps.*

1. **Mines and traps** laid by a skilful enemy are most difficult to detect, and their successful action can only be circumvented by a thorough and conscientious search. During an advance the country must be systematically examined, whenever the enemy is suspected to have employed these devices. Specially trained parties of engineers, acting in close co-operation with the infantry, should be used for this purpose. They should be equipped with probing bars, electric torches and wire-cutters.

In searching suspected localities, contact and delay action mines may be detected from the following:—

- i. Disturbed appearance of surface soil, breaks in the continuity of weeds, &c.
- ii. Small subsidences in the ground; these are likely to be accentuated by rainy weather.
- iii. Presence of spoil, explosive wrappings, boxes, &c.
- iv. Foot prints in soil foreign to the surface of the ground, *e.g.*, chalk marks where no chalk exists on the surface.
- v. Pegs or other marks placed in the ground without any obvious reason.

Delay action mines, since they require no contact making device near the surface, are particularly difficult to discover.

Where the enemy is using shells for the explosive charge, the deflection of a magnetic needle in the presence of iron may sometimes be a valuable aid to detection, especially in searching walls of dug-outs and buildings. In such cases search parties should be provided with compasses and dip needles.

Search parties should be carefully instructed in the various types of mines and traps which are likely to be encountered. When any new form is discovered, it should be reported immediately and a description rendered of its salient features. By this means all troops can be warned quickly and search parties placed on the look out for devices of the same type.

2. **The removal or rendering harmless** of mines and traps is a dangerous operation and should only be carried out by experts. In some cases the extraction of the firing device and detonator may be effected without danger and the bulk explosive left *in situ;* in others, it may be advisable to remove the whole charge carefully and explode it in a safe place. Where the charge is fired electrically the wires of the circuit should be cut and the electric detonator removed. With delay action mines the fuze should be removed immediately it is discovered. Particular care must be exercised in doing so as the slightest jar may send it off. Explosives should not be thrown in ponds or down wells as they may poison the water.

APPENDIX III.

Table of Time, Men and Tools Required for the Execution of certain Field Works.

It is assumed that :—

i. All tracing and marking out has been done beforehand.
ii. Materials are on the site of the work, except when provision for carrying is made.
iii. The labour is ordinarily trained infantry working parties.
iv. Rain is not falling.
v. The march to work does not exceed 1½ hours.

Nature of work.	Unit or party.	Time.	Amount of work.	Tools for each party.	Remarks.
I.—Entrenching.					
Excavation	1	1 hour	20 cubic feet ...	1 Pick ... ... 1 Shovel	(a) Soil average easy; increase by 50 per cent. for very easy soil; decrease by 30 per cent. for very difficult soil. (b) Decrease by 30 per cent. for very dark nights.
	1	4 hours	60 cubic feet ...	Do.	(c) Maximum throw 12 feet and lift 4 feet, or maximum lift only 9 feet. When these maxima are exceeded, one shoveller, with one shovel, is required for every two diggers. (d) When depth of trench exceeds 4 feet, one shoveller, with one shovel, is required for every two diggers, to clear berms and level parapet; parados must be left heaped and uneven.

					(e) In heavy clay provide sticks as scrapers. (f) Officer in charge of work is responsible for the provision of any special tools, such as crowbars, spare pick handles, spades, axes, billhooks, &c., required by the nature of the soil. (g) One pick between two diggers or one pick between three diggers will suffice in certain soils.
2. Moving earth 25 yards, depositing and return	1	2 mins.	1 cubic foot ...	2 wheelbarrows ...	(a) Spare wheelbarrows or stretchers being filled while the others are being emptied.
	2	2 mins.	1 cubic foot ...	2 stretchers	
	1	2 mins.	½ cubic foot ...	1 sandbag	(a) Sandbags ready filled—dumped, but not emptied.
3. Filling sandbags ...	3	1 min.	1 bag	3 shovels	(a) Sandbags to be three-quarters filled.
II.—Revetments, &c.					
1. Sandbag revetment— i. Filling sandbag ... ii. Carrying sandbags to site, &c.			*See* I. 3, above. *See* I. 2, above.		(a) Size of sandbag 20 by 10 by 5 ins. (b) Alternate courses of headers and stretchers.
iii. Building sandbags	2	2 mins.	1 square foot of revetment	2 filled bags ... ... 1 flat beater	(c) Flat beater may be a billhook or a spade.

Nature of work.	Unit or party.	Time.	Amount of work.	Tools for each party.	Remarks.
II.—Revetments, &c.—*continued.*—					
2. Sod revetment:—					
i. Cutting sods ...	3	3 mins.	5 sods	3 sharp spades ...	(*a*) Size of sod 18 by 9 by 4½ ins.
ii. Carrying sods to site, &c.			*See* I. 2, above.		(*b*) 1 sod to be taken as ½ cubic foot.
iii. Building sods ...	2	3 mins.	1 square foot of revetment	1 shovel or spade ...	(*c*) Allow 5 sods, each 18 by 9 by 4½ ins. for each square foot of surface revetted 18 ins. thick.
3. Sheeting and anchored pickets	10	30 mins.... ...	10 feet run of revetment	2 mauls (*g*) ... ... 1 saw 1 billhook 1 pair pliers 2 shovels 1 pick 1 crowbar	(*a*) Trench cut to section. (*b*) Sheeting consisting of C.G.I. sheets, planking, hurdles or X.P.M. (*c*) Wire, sharpened pickets, and sheeting distributed at frequent intervals on site. (*d*) 1 anchorage picket to each main picket. (*e*) 8 strands of wire from each picket to anchorage. (*f*) Anchorage pickets 8 feet from main pickets. (*g*) With angle iron pickets use sledge hammers instead of mauls. (*h*) 2 men on anchorage pickets. 2 men on main pickets. 2 men sheeting. 2 men wiring. 2 men filling and trimming.

4. Sheeting and small "A" frames	7	30 mins.... ...	10 feet run (of trench)	2 picks ... ... 2 shovels 2 mauls 2 spades 1 saw 1 hammer nails	(a) Trench cut to section. (b) Materials distributed at frequent intervals. (c) Sheeting consisting of C.G.I. sheets, planking, hurdles or X.P.M. (d) Allow 15 mins. for each corner. With rounded corners time includes bending C.G.I. sheets as required. (e) 2 men supplying materials. 2 men trimming and packing. 3 men placing frames.
5. Gabions, placing and filling	1	5 mins.	1 square foot revetted	1 shovel ... ... 1 pick	(a) Square gabions 1 ft. 6 ins. wide and 3 ft. high; area revetted 4½ sq. ft., contents 6¾ cub. ft. Earth to be excavated.
6. Picket trestles and laying trenchboards on same	5	15 mins.... ...	6 feet run (of trench)	1 maul ... ... 2 saws 2 hammers nails	(a) Pickets distributed on site. (b) Trestles at one foot intervals.
7. Trenchboards laying on "A" frames	3	10 mins.... ...	10 feet run (of trench)	1 saw ... ... 1 hammer nails	(a) 1 man supplying material; 2 men laying and fitting. (b) Allow 10 mins. for each corner.
8. Hurdles, rough, making	3	20 mins.... ...	1 hurdle ...	2 billhooks ... ... 2 knives 1 mallet 1 pair pliers	(a) Materials: 75 lbs. brushwood and 60 ft. of wire or yarn for each hurdle, 6 ft. by 3 ft. (b) Weight of each complete, about 56 lbs. (c) Brushwood ready cut on site.
9. Fascines, making ...	4	1 hour	1 fascine ...	3 billhooks ... ... 1 handsaw 1 pair pliers 2 knives 1 maul 1 choker	(a) Materials: 200 lbs. of brushwood and 60 ft. of wire or hoop-iron (40 ft.) for each fascine, 18 ft. long by 9 ins. diam. (b) Weight complete about 140 lbs. (c) Cradle for making requires ten pickets, 6 ft. 6 ins. by 3 ins. diam. (d) All materials on site.

APPENDIX III—*continued.*

Nature of work.	Unit or party.	Time.	Amount of work.	Tools for each party.	Remarks.
III.—CUTTING AND FELLING.					
1. Trees, felling	1	1 min.	1 in. in diam. ...	1 felling-axe or saw	(*a*) Up to 12 ins. diam. If over 12 ins. diam., allow time in mins. = $\frac{d^3}{144}$ where "d" = mean diam. in inches. (*b*) If only hand-axes are available allow twice the time as calculated in both these rules.
2. Woods, clearing of brushwood and small trees	10	$2\frac{1}{2}$ mins.... ...	20 sq. yards (up to 12 ins. diam.)	10 billhooks ... ... 4 felling-axes 2 saws, cross-cut 4 saws, hand 1 grindstone 2 whetstones	(*a*) All hands felling at first, then a proportion detailed for collecting and removing according to purpose in view. (*b*) Produce: about 5 lbs. brushwood for each 1 sq. yard.
3. Hedges, cutting stems	2	5 mins.	1 yard run (up to 2 ins. diam.)	1 billhook or hand-axe 1 saw 3 fathoms of rope	(*a*) Average stiff thorn hedge. (*b*) If necessary use rope to expose lower stems to the cutting tool.
4. Brick walls, cutting loopholes in	1	30 mins.... ...	1 loophole ...	1 pick or 1 crowbar...	(*a*) Up to 18 ins. thick. (*b*) If possible, obtain a mason's chisel and hammer.
5. Brick walls, notches in	1	10 mins.... ...	1 notch	1 pick or 1 crowbar	(*a*) Up to 18 ins. thick. (*b*) If possible, obtain mason's chisel and hammer.

IV.—WIRE ENTANGLEMENTS.					
1. Wire entanglements (French)	10	Day, 10 mins. ... Night, 20–30 mins.	50 yards ...	1 pair pliers ... ... 9 windlassing sticks Gloves, if desired 26 long pickets 4 anchorage pickets 6 coils French wire 24 staples 3 coils barbed wire* 2 spirals barbed wire	*(a) Two coils barbed wire for thickening entanglement, if spirals are not available.
2. Standard double belt of concertinas	8	Day, 20 mins. ... Night, 30-35 mins.	50 yards ...	1 pair pliers ... ... 7 windlassing sticks Gloves, if desired 34 long pickets 4 anchorage pickets 16 concertinas 2 coils barbed wire*	
3. Standard low (or knee-high) wire entanglement	8	Day, 30 mins. ... Night, 1-1½ hours	50 yards ...	1 pair pliers ... ... 7 windlassing sticks Gloves, if desired 54 medium pickets 2 coils barbed wire * 3 coils barbed wire (50 yards) 4 spirals	*(a) Four coils barbed wire for thickening entanglement, if spirals are not available.
4. Standard double apron fence	11	Day, 30 mins. ... Night, 45-60 mins.	50 yards ...	1 pair pliers ... ... 10 windlassing sticks 20 long pickets 40 short pickets 7 coils barbed wire*	
5. Entangling hedges, &c. rough abatis	8	20 mins.... ...	50 yards ...	2 billhooks ... ... 2 pairs pliers 5 coils barbed wire (50 yards)	

* Coils of barbed wire are 130-yard coils unless otherwise stated.

APPENDIX IV.

Table of Time and Men Required for the Execution of Certain Bridging Operations.

It is assumed that:

i. The work is being carried out by day, under fair weather conditions.
ii. The labour is trained R.E. personnel (except where otherwise stated).
iii. Material is ready at site.
iv. The current does not exceed 3 knots.
v. The banks and bed present no exceptional difficulty.

Operation.	Party.	Time.	Remarks.
Construct a petrol-tin pier for an infantry assault bridge	4 men	1 hour	R.E. or Infantry Pioneers.
Construct a barrel-pier of 54 gal. casks	16 men	40 mins.	
Erect a steel trestle	12 men	½ hour	
Bridge a 50-yard river with—			
(*a*) Light timber trestle bridging (Pack bridge)	60 men	8 hours	Depth of water not exceeding 10 feet.
(*b*) Infantry assault bridging ...	50 men	30 mins.	Includes carrying complete bridge 600 yards and launching. Bridge assumed to be assembled beforehand. 2 men for each pier, R.E. or Infantry, plus spare men.
Assembling and launching steel stock-span bridge (Martel box girder), 96 feet, 4 girders.	60 men	16 hours	Time necessary for abutment and foundations depends on local circumstances.
Building 120′ medium pontoon bridge with 250′ sleeper road approaches.	150 men	3 hours	100 R.E. and 50 Infantry.

APPENDIX V.

TABLES OF TOOLS AND EXPLOSIVES CARRIED IN THE FIELD.

TABLE I.—*Tools.*

i.—Other than those allowed for machine guns or as cart or wagon equipment.

Detail.	Cavalry Regiment.	Horse Artillery Battery.	18 Pdr. Battery.	4·5-in. Howitzer Battery.	Pack Battery.	60-Pdr. Battery.	6-in. Howitzer Battery.	Anti-aircraft Battery.	Field Squadron.	Field Company.	Field Park Company.	Headquarters Infantry Brigade.	Infantry Battalion.*	Tank Battalion.	Armoured Car Company.	Divisional Reserve.(a)
Axes, felling	14	6	4	2	4	4	4	8	64	49	18	—	16	19	2	—
Axes, hand	7	—	—	—	—	—	—	—	48	40	10	1	8	19	2	—
Axes, pick	12	36	24	28	16	24	4	24	72	107	49	550	76	18	30	435
Crowbars	3	3	2	2	2	2	4	8	12	8	4	2	8	8	22	—
Hooks, bill	12	18	12	14	8	8	4	24	40	39	16	—	20	13	2	—
Hooks, reaping	47	—	—	—	48	—	—	—	16	13	3	—	20	—	—	—
Sandbags	—	—	—	—	—	—	—	—	200	400	400	—	—	—	—	—
Saws, cross-cut	—	—	—	—	—	2	2	—	8	4	6	—	—	4	—	—
Saws, folding	3	—	—	—	—	—	—	—	12	4	4	—	12	—	—	—
Saws, hand	4	24	16	20	—	4	4	10	40	35	35	—	1	20	—	—
Shovels	19	36	24	28	48	28	28	24	96	111	60	840	100	40	16	860
Spades...	—	30	20	24	—	20	4	24	8	10	10	—	10	5	4	—

(a) Carried by Field Park Company, R.E.

Appendix V—*continued*.

ii.—Cart, wagon and machine gun equipment.

Detail.	Axes, Felling.	Axes, Pick.	Hooks, Bill.	Shovels.	Spades.
Carts, Maltese	1	1	1	2	—
Carts, Officers' Mess	1	—	1	—	—
Carts, water	—	1	—	1	—
Wagons, G.S.	1	1	1	2	—
Wagons, telephone	1	1	1	—	1
Machine Guns—					
Vickers, for each gun	—	1	1	2	—
Hotchkiss (Cavalry) for each gun	—	1	—	1	—
Lewis (Infantry), for every 8 guns	—	4	—	4	—

APPENDIX V—*continued.*

TABLE II.—*Explosives.*

Explosives (Demolition) authorized in War Equipment Tables to be carried by units in the field.

Detail.	With each Field Co., R.E.	With S.A.A. Section Ammunition Company R.A.S.C.†	Total with Division.	With Field Squadron R.E.	With S.A.A. Section Cavalry Ammunition Company R.A.S.C.†	Total with Cavalry Division.	With Maintenance Company, R.A.S.C.†	With Cavalry Maintenance Company, R.A.S.C.†	With Army Troops Co., R.E., and Corps Troops Maintenance Company, R.A.S.C.† (each).
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Gun-cotton, dry primers, field, 1 oz. ...	720	540	2,700	480	480	960	240	240	720
Gun-cotton, wet slabs, field, 16 oz. ...	728	546	2,730	(a) 1,120	(a) 1,120	2,240	280	560	448
Detonators, No. 8	400	300	1,500	400	400	800	150	200	300
Detonators, electric, No. 13	200	150	750	400	400	800	75	200	200
Fuze, safety, No. 11 ... ... fms.	224	168	840	192	192	384	84	96	192
Fuze, instantaneous, detonating... feet	1,600	1,200	6,000	1,600	1,600	3,200	600	800	1,600
Matches, vesuvian...	416	312	1,560	624	624	1,248	156	312	208

(a) Until present stocks of boxes, gun-cotton, wet, field, No. 2, W.32, containing 16 slabs, are used up, the scale will be 1,152.
(†) This nomenclature will be correct when the necessary changes have been introduced into war establishments.

APPENDIX VI.

TABLE GIVING LOADS FOR MAN, G.S. WAGON AND 3-TON LORRY, FOR ENGINEERING STORES IN GENERAL USE IN THE FIELD.

[NOTE.—The loads are based on fair conditions only—*i.e.*, a man at 30 lbs. a G.S. wagon at 1,900 lbs., and a 3-ton lorry at 5,600 lbs.; under good conditions, the load of a man may be increased to 40-lbs. and the loads of a G.S. wagon and a 3-ton lorry by one-sixth. Man loads to be "bundled" beforehand, whenever possible.]

Item.	Article.	Description.	One man load.	G.S. wagon load.	3-ton lorry load.
1	Sandbags...	Bales of 250; weight, 96 lbs	50 to 75	20 bales	60 bales
2	Wire, barbed	No. 12½, S.W.G., 130 yds., 32 lbs.	1	70	200
	" "	No. 14, S.W.G., 176 yds., 32 lbs.	1	70	200
3	Pickets, screw, long ...	5 ft. 7 ins. long, 4 eyes; weight 6 lbs.	4	200	600
4	" " short ...	2 ft. 1½ ins. long, 2 eyes; weight 2¾ lbs.	12	500	1,630
5	Pickets, angle, long ...	6 ft. long; weight, 14 lbs.	2	150	400
6	" " medium	3 ft. 6 ins. long; weight, 9 lbs.	4	220	650
7	" " short ...	2 ft. long; weight 4½ lbs.	8	440	1,300
8	Pickets, brushwood, long	5 ft. long, 3½ to 4 ins. diameter; weight, 9 lbs.	4	200	600
9	Pickets, brushwood, short	2 ft. 6 ins. long, 2½ to 3 ins. diameter; weight 3 lbs.	8	600	1,800
10	Wire entanglements (French) bundle	Weight of coil about 19½ lbs.	2 coils	100 coils *or* 20 bundles	275 coils *or* 55 bundles
11	Wire entanglements (French) staples	Boxes of 300; weight, 160 lbs.	—	12 boxes	35 boxes
12	Wire entanglements (French) spikes	100 weigh 32 lbs. ...	100	6,000	—
13	Wire, galvanized, iron, coil	No. 14, S.W.G.; weight, 56 lbs., 100 lbs. per mile	½ coil	40 coils	100 coils
14	Wire, netting, roll ...	3 ft. wide, 50 yds. in roll; weight, 80 lbs.	20 yds.	24 rolls	70 rolls
15	Expanded metal, sheets	6 ft. 6 ins. long by 3 ft. wide; weight, 8½ lbs. In cases of 20 sheets	3 sheets	200 sheets	600 sheets
16	Corrugated iron, 6 ft. sheets	Width, 2 ft. 2 ins.; weight, 16 lbs.	2	120	350
17	Corrugated iron, 7 ft. sheets	Width, 2 ft. 2 ins.; weight, 18½ lbs.	1½	100	300
18	Corrugated iron, 9 ft. sheets	Width, 2 ft. 2 ins.; weight, 28 lbs.	1	70	200
19	Felt, roll	3 ft. wide, 25 yards in roll; weight, 85 lbs.	10 yards	22 rolls	66 rolls
20	Canvas, Hessian, roll ...	3 ft. wide, 110 yards in roll; weight, 70 lbs.	50 yards	27 rolls	80 rolls
21	Canvas, rot-proof, roll ...	5 ft. wide, 120 yards in roll; weight, 130 lbs.	30 yards	14 rolls	40 rolls

APPENDIX VI—*continued.*

Item.	Article.	Description.	One man load.	G.S. wagon load.	3-ton lorry load.
22	"A" frames (small) ...	Weight, 30 lbs. ...	1	40	120
23	Trench boards	6 ft. long; weight, 35 lbs.	1	35–40	120–150
24	Timber, 4-in. by 2-in. ...	F.R.; weight, 2¼ lbs.	—	750 F.R.	2,250 F.R.
25	Timber, 9-in. by 3-in. ...	F.R.; weight, 9 lbs.	—	200 F.R.	600 F.R.
26	Planking, 1-in.	Supplied by the foot run	Dependent on width of planking. Weight of soft timber may be taken as 40 lbs. per cubic foot.		
27	Planking, 1½-in.				
28	Planking, 2-in.				
29	Pit prop, 9 ft. long	6-ins. diameter; weight, 90 lbs.	—	25	75
30	Pit prop, 9 ft. long	9-ins. diameter; weight, 180 lbs.	—	12	36
31	Cement, cask	400 lbs.	—	5	14
32	Sand	—	½ sandbag	¾ cub. yd.	2¼ cub. yds.
	Gravel	—	,,	,,	,,
	Chalk	—	,,	,,	,,
	Earth	—	,,	,,	,,
33	Corrugated steel shelter, large	*See* Plate **142** for quantities	—	½	1
34	Corrugated steel shelter, small	—	—	1 in 1 G.S. wagon; 3 in 2 G.S. wagons	5
35	R.S.J. 9 ft. by 5 ins. by 3 ins.	100 lbs.	½	19	56
36	Nails—				
	1-in.	800 to 1 lb.			
	2-in.	122 to 1 lb.			
	3-in.	52 to 1 lb.			
	4-in.	30 to 1 lb.			
	5-in.	20 to 1 lb.			
	6-in.	14 to 1 lb.			
37	Staples, No. 8 S.W.G. ...	50 to 1 lb.			
38	Shovels	Weight, 5 lbs. ...	6	400	1,200
39	Picks	Weight, 8 lbs. ...	4	240	700
40	Tapes, tracing	In 50-yard rolls ...	12	—	—

APPENDIX VII.

Principal Tools, Materials, and Stores Suitable for Use in Field Engineering.

The tools and stores provided for the peace instruction of regular troops in field engineering are as laid down in Section XV, and Appendix VI. Equipment Regulations, Part I, 1923. *The tools and stores forming war equipment of units are similarly detailed in the various sections of Part II, Equipment Regulations, and in Mobilization Store Tables* (A.F.G. 1098) *or War Equipment Tables.*

The following tables of tools, materials, and stores are intended as guides for the selection and preparation of articles, suitable for use in war, for such operations of field engineering as are described or indicated in this manual.

The method of obtaining supply of such articles will follow the instructions laid down in Field Service Regulations, and Ordnance Manual (War).

The special equipment required for the following engineer services is not included in these tables, except in so far as certain articles comprised therein may be suitable for general field engineering purposes:—

Electrical instruments and electric light stores.
Railway tools, plant and armoured trains.
Survey instruments and stores.

Demand and issue, except where otherwise stated, are "per article."

The tables in this Appendix are:—

1.—Tools, entrenching.
2.—Tools, cutting.
3.—Tools and stores, miscellaneous.
4.—Sandbags, canvas, &c.
5.—Corrugated shelters and iron sheets.
6.—Rolled steel joists and rails.
7.—Posts and pickets.
8.—Materials supplied for camouflage.
9.—Timber.
10.—Cordage.
11.—Bridging and boat stores.
12.—Wire and wire rope.
13.—Bolts, dogs, nails and spikes.
14.—Water supply stores.
15.—Demolition stores.

APPENDIX VII—*continued.*

TABLE 1.—*Tools, entrenching.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
2B	Axes, pick, heads	$4\frac{1}{2}$ lbs. and 8 lbs.	
2B	,, ,, helves	36 ins. ferruled and plain	
2B	Barrows, hand, single	5 ft. 4 ins. by 2 ft.	
2B	,, wheel, entrenching, with wheels	Wood-wheels, flat tyre	
2B	Crowbars, chisel and claw ends	5 ft. 6 ins., 31 lbs., 4 ft. 6 ins., 20 lbs., 3 ft. 6 ins., 12 lbs.	
29D	Picks, miners, heads	$4\frac{1}{2}$ lbs.: steel	
29D	,, ,, helves	24 in.	
29D	Picks, push	30 ins., 3 lbs. 6 oz. (heart shaped, straight stabbing).	
2B	Shovels, G.S.	32 in. helve, $3\frac{1}{2}$ lbs., curved	
2B	,, R.E.	32 ins. helve, 5 lbs., curved and stout	
29D	,, miners		
29D	,, ,, helves	16 to 18 in.	
2B	Spades, Mark III	$32\frac{3}{4}$ ins. helve, straight, $5\frac{3}{4}$ lbs. ...	

TABLE 2.—*Tools, cutting.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
7	Adzes, carpenters, handled ...	$4\frac{1}{2}$ lbs.	
2A	Axes, felling	$34\frac{1}{2}$ ins. helve, $4\frac{1}{2}$ lbs.	
2A	Axes, hand	16 ins. helve, 2 lbs. 2 oz.	
7	Chisels, brick	18 ins., $1\frac{1}{2}$ ins. end	
7	,, hand, cold	Metal cutting, 1 in., $\frac{7}{8}$ in. and $\frac{5}{8}$ in. wide	
7	,, firmer	Wood-cutting, blades $1\frac{1}{2}$ ins. to $\frac{1}{16}$ in. wide	
7	Cutters, wire, large	Long compound lever...	
7	Files, saw taper, 2nd cut, single	4 ins. for handsaw, 2 oz.	
7	,, smooth, three square ...	6 in. for cross-cut, 3 oz.	
7	Grindstones, F.S.	14 ins. and 10 ins.	
2A	Hooks, bill	2 lbs. 3 oz.	
2A	,, reaping	1 lb. 5 oz.	
7	Oilstones, carpenters, 9 in. wooden frame.		
7	Pliers, side-cutting	8 ins. and 5 ins. long	prs.
7	Saws, cross-cut	5 ft. blade, $6\frac{1}{2}$ lbs.	
7	,, folding, in leather case ...	3 ft. 9 ins. blade, 2 handles, 1 lb. 12 oz.	
7	,, hand	26 ins. and 20 ins.	
28C	Sets, cold, large	15 ins. handle; for cutting steel wire rope, &c.	
7	,, saw, hand	Notched screwdriver at end, 4 oz. ...	
7	,, ,, pit and cross-cut ...	Cross spike at end, 12 oz.	
7	Stones, rag	For reaping hooks, &c.	doz.

APPENDIX VII—*continued*.

TABLE 3.—*Tools and stores, miscellaneous*.

(Not included in Tables 1 or 2.)

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
7	Anvils (with blocks)	1 cwt.	
29D	Bars, boring, and jumping, Nos. 1, 2, 3, 6, 7 and 8	Steel, octagonal, chisel end, for rock, 3$\frac{1}{8}$ ins. wide, 2 ft. 6 ins. long; 3 ins. wide, 3 ft. 6 ins. long; 2$\frac{7}{8}$ ins. wide, 4 ft. 6 ins. long; 1$\frac{1}{2}$ ins. wide, 2 ft. long; 1$\frac{5}{8}$ ins. wide, 3 ft. long; 1$\frac{1}{4}$ ins. wide, 4 ft. long	
29D	Bars, boring and jumping, Nos. 4, 5, 9 and 10	Steel, octagonal, chisel pointed both ends, 1$\frac{1}{8}$ ins. wide, 5 ft. 6 in. long; 1 in. wide, 7 ft. long; 2$\frac{3}{4}$ ins. wide, 5 ft. 6 ins. long; 2$\frac{5}{8}$ ins. wide, 7 ft. long	
29D	Bars, pinching (spike and lever)	2$\frac{1}{2}$, 3, 3$\frac{1}{2}$ and 4 ft. long	
8A	Blocks, tackle, G.S., malleable, cast iron, galv.	Single, double, treble, and snatch (and size of cordage)	
29D	Blowers, Holman	With hose and wrenches; for ventilating mines, &c.	
29D	Baskets, miners	For raising earth from shafts... ...	
29D	Candlesticks, miners	With bottom and side spikes ...	
29D	Chokers, fascine	2 four ft. levers and 4 ft. chain ...	
7	Forges, field, G.S.	276 lbs. and poker, slice, tongs and vice	
29D	Grapnels, iron	2, 3, 16, 40 and 50 lbs.	
7	Hammers, claw	32 oz., 24 oz. and 16 oz.	
7	Hammers, masons	5 lbs. chisel point	
29D	Hammers, miners, boring ...	5 and 7 lbs.	
29D	Hammers, miners, sledge ...	14 lbs.	
29A	Jumpers, steel	For post holes, 2 ft. 9 ins. by 2 ins., 27 lb. 10 oz.	
29A	Ladders, field telegraph ...	16 ft. 6 ins. in 2 lengths	
29D	Ladders, rope, miners	20, 30 and 50 ft.	
N.I.V.	Lamps, acetylene	Land and portable and calcium carbide	
N.I.V.	Lamps, electric	Land and portable and spare accumulators	
11	Lamps, hurricane, Globe ...	... ...	
29B	Levels, F.S., Mk. IV, plumb bobs	... ...	
2A	Mauls, G.S., with helves ...	14 lb.	
8D	Rods, measuring, common ...	Wood, 10 ft. and 6 ft. marked 3 ins....	
29D	Scrapers, miners	6 ft. by $\frac{1}{2}$ in. with 2 in. diameter, scraper each end; 6 ft. by $\frac{3}{8}$ in. with 1 in. diameter, scraper each end	
29D	Scrapers, earth	7 ft. long; 9 lbs.	
7	Spanners, adjustable	15 ins.	
7	Spanners, McMahon	15 ins. and 12 ins.	
8D	Tapes, measuring, metallic woven	In leather case, 100 ft.	
2B	Tapes, tracing	50 yds.; 1$\frac{1}{2}$ ins. white web.	
29D	Trucks, miners, elm	69 lbs.; for removing earth in saps and mines	
7	Vices, standing, 36-lb.	Jaws 4 ins. wide	
12	Winches, Nos. 1 and 2	Hand power winches, to lift 25 and 50 tons	

APPENDIX VII—*continued.*

TABLE 4.—*Sandbags, canvas, &c.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
2A	Canvas, rot-proof	5 ft. wide ; 120 yds. in roll	Yards.
13C	Canvas, Hessian	28 ins. wide ; 110 yds. in roll ...	,,
13C	Cloth, union, anti-gas	54 ins. wide ; 74 yards in roll ...	,,
10B	Covers, waterproof, black or green	Sizes in feet : 40 × 20, 30 × 20, 24 × 18, 20 × 15, 12 × 10	
N.I.V.	Felt, roofing	3 ft. wide ; 25 yards in roll	Roll.
N.I.V.	Sheeting, corrugated iron ...	2 ft. 3 ins. wide ; in 6-ft., 7-ft. and 9-ft lengths	
29D	Sandbags	Bales of 250	Bales.

TABLE 5.—*Corrugated shelters and iron sheets.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
N.I.V.	Straight sheets, black or painted	6 ft. to 9 ft. by 2 ft. 2 ins., 22 or 24 gauge, 10 sheets to bundle	Bundles
N.I.V.	Straight sheets, painted black or galvanized.	7 ft. by 2 ft. 2 ins., 22 gauge, 10 sheets to bundle	,,
N.I.V.	Curved sheets for bivouac shelter	9 ft. by 2 ft. 2 ins., 18 gauge, bent to 7 ft. radius. Carries one layer of sandbags or equivalent weight. 5 sheets to bundle	,,
N.I.V.	Curved sheets for bivouac shelter	9 ft. by 2 ft. 2 ins., 22 gauge, bent to 9 ft. radius. Will carry no weight. 10 sheets to bundle	,,
N.I.V.	Corrugated steel shelter, large ...	17 ft. 9 ins. by 9 ft. 6 ins. by 6 ft. 2½ ins. inside dimensions. Made up of 21 curved plates 7 ft. by 2 ft. 9 ins., each with six 5-in. corrugations	
N.I.V.	Corrugated steel shelter, small ...	12 ft. 9 ins. by 5 ft. 3 ins. by 3 ft. 8 ins. inside dimensions. Made up of 10 curved plates 5 ft. 6½ ins. by 2 ft. 9 ins. each with five 6-in. corrugations	
N.I.V.	Troughing...	6 ft. or 9 ft. long, 3 ft. 3 ins. wide ...	

APPENDIX VII—*continued.*

TABLE 6.—*Rolled steel joists and rails.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
N.I.V.	Joist steel, rolled—		
N.I.V.	12 ins. by 5 ins.	Length 22 ft., 32 lbs. a foot run ...	
N.I.V.	10 ins. by 5 ins.	Length 20 ft., 30 lbs. a foot run ...	
N.I.V.	9 ins. by 4 ins.	Length 18 ft., 21 lbs. a foot run ...	
N.I.V.	8 ins. by 4 ins.	Length 16 ft., 18 lbs. a foot run ...	
N.I.V.	5 ins. by 3 ins.	Length 9 ft., 11 lbs. a foot run ...	
N.I.V.	Rail, steel, bullheaded—		
N.I.V.	40 lbs.	Height $3\frac{1}{2}$ ins., $13\frac{1}{2}$ lbs. a foot run ...	
N.I.V.	60 lbs.	Height $4\frac{1}{2}$ ins., 20 lbs. a foot run ...	
N.I.V.	80 lbs.	Height 5 ins., $26\frac{1}{2}$ lbs. a foot run ...	

TABLE 7.—*Posts and pickets.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
29D	Pickets, angle steel, long ...	6 ft. 0 ins. long	
	,, ,, medium ...	3 ft. 6 ins. long	
	,, ,, short ...	2 ft. long	
29D	,, screw, long	5 ft. 7 ins. long, 4 eyes	
	,, ,, short	2 ft. $1\frac{1}{2}$ ins. long, 2 eyes	
29D	Pickets, brushwood—		
	Short	2 ft. 6 ins. long, $1\frac{1}{2}$ ins to 2 ins. diam.	
	Long	5 ft. long, 3 ins. to 4 ins. diameter ...	
	Gabion	3 ft. 6 ins. long	
	Tracing	1 ft. 6 ins. long	
	Barked	For night work	
	Unbarked	For day work	
	Pickets, square—		
	Long	5 ft. long	
	Short	2 ft. 6 ins. long	
	Tracing	9 ins. long	

TABLE 8.—*Materials supplied for camouflage.*

FOR CONCEALMENT OF FIELD WORKS, BATTERIES, &C.

1. Fish netting in 30 feet by 30 feet squares, or wire netting in rolls 30 feet by 6 feet, garnished with canvas knots, with or without irregular islands of scrim (an open mesh form of canvas), mainly for use in open country.

APPENDIX VII—*continued.*

TABLE 8—*continued.*

2. Fish netting (30 feet by 30 feet) or wire netting (30 feet by 12 feet), furnished only with large islands of scrim, for use in broken country. Fish nets (10 feet by 10 feet) with raffia.

3. Irregular patches of scrim, with or without bare rolls of wire netting 30 feet by 6 feet, to be used for supplementing, or actually making up material mentioned in para. 2 *in situ.*

4. Scrim sheets, 30 feet long by 6 feet or 12 feet wide, for covering spoil, sandbags, &c., or any other light-toned objects under material as in paras. 1, 2 or 3 above.

5. Posts 2 inches by 2 inches, of varying lengths, pickets and wire, for supporting camouflage.

SNIPER'S REQUISITES.

6. "Symien" pattern, consisting of loose-fitting jacket, with hood attached, separate legs, rifle cover and gloves.

7. Dummy heads for locating enemy snipers.

TABLE 9.—*Timber.*

(NOTE.—Timber may be either felled and trimmed on the spot, collected from timber stores in adjacent towns or villages, obtained by dismantling structures containing timber, or demanded from the engineer parks and dumps. The following table gives the ordinary sizes in which timber may be expected to be available.)

Section in Vocab. of Stores.	Designation.	Size.	—
4	Planking	$\frac{3}{4}$ in. ... ... 1 in. ... ... $1\frac{1}{2}$ ins. ... ... 2 ins.	In various widths and lengths. Demand by the foot run.
4	Scantlings ...	3 ins. by 3 ins.... 4 ins. by 2 ins.... 4 ins. by 3 ins. ... 4 ins. by 4 ins. ... 6 ins. by 3 ins. ... 6 ins. by 4 ins. ... 6 ins. by 6 ins. ... 9 ins. by 3 ins. ... 9 ins. by 4 ins. ... 9 ins. by 6 ins. ... 9 ins. by 9 ins. ...	In various lengths. Demand by the foot run, giving a minimum "piece length" for 6 ins. by 6 ins., 9 ins. by 6 ins., and 9 ins. by 9 ins.
4	Baulks	10 ins. by 10 ins. 12 ins. by 6 ins. 12 ins. by 12 ins. 14 ins. by 12 ins. 16 ins. by 8 ins.	In various lengths. Demand by the piece.
4	Spars	—	In various sizes and lengths. Demand by the piece, specifying length and diameter.
N.I.V.	Pit props	—	In various sizes and lengths. Demand by number, specifying diameter and length.

APPENDIX VII—*continued.*

TABLE 10.—*Cordage.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
8A	i. Cordage, hemp, hawser, 3-strand	Service cordage in general use; either *tarred* or *white*; in the following sizes, circumference in inches:—7, 4, 3½, 3, 2½, 2, 1½, 1. *Tarred* cordage is weaker, but will stand exposure to weather better than *white*.	Fathom [coils of 113 fms.]
8A	ii. Cordage, manilla, hawser, 3-strand	A stronger cordage, in the following sizes, circumference in inches:—5, 4, 3½, 3, 2½, 2, 1½, 1	"
8A	iii. Cordage, coir, hawser, 3-strand.	A coarse, light, elastic, cordage, which will float upon water, but has only one-fourth the strength of hemp cordage of same size. Sizes:—7, 6, 5, 4, and 3 ins.	"
8A	iv. Lashings, falls, guys, &c. ...	Cordage, as in i. above, of sizes as under:— 3 ins. Footropes, 9 fms.; cables, 30 fms.; falls, 50 fms.; guys, 30 to 36 fms. 2½ ins. Slings for cask piers, 6 fms. 2 ins. Falls, 50 fms.; lashings, 6 and 9 fms. 1½ ins. Braces, 3 fms.; breast lines, 10 fms.; lashing, 6 fms. 1 in. Buoy lines, 10 fms.; lashings, 3 and 6 fms.	"
8A	v. Small cordage, yarn, twine, &c. Cordage, spun yarn, hemp Lines, Hambro	 3-thread, tarred, rough ... ... 150 ft., strong and light	 Cwt.

TABLE 11.—*Bridging and boat stores.*
(*See also* Military Engineering, Vol. III.)

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
29C	Anchors, pontoon	1 cwt. and ½ cwt.	
29C	Bailers, pontoon	Tin, with handle	
29C	Baulks, plain	15 ft. 9¾ ins. by 3½ ins. to 1½ ins. by 6 ins.; 56 lbs.	
29C	" shore end, inside ...	3 ft. 7 ins. long; 3 to set; 15½ lbs. each	
29C	" " " outside ...	3 ft. 6½ ins. long; 2 to set; 21½ lbs. each	
29C	Beams, saddle	In two pieces · -8 lbs. pair	

APPENDIX VII—*continued.*

TABLE 11—*continued.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
29C	Buoys, anchor	4 lbs. $10\frac{1}{2}$ ozs.	
9A	Chalk, prepared	White or coloured ; 144 pieces ...	Box.
29C	Chesses, solid	10 ft. by 12 ins. by $1\frac{1}{2}$ ins. ; 45 lbs....	
20	Drivers, pile, Swiss	With steel guide rod ; about 130 lbs. ; hand power.	
29C	Hooks, boat and stave	11 ft. $7\frac{1}{2}$ ins. long	
8B	Life-belts, cork.		
8B	Life-buoys, Mk. IV	Reindeer hair, covered canvas ...	
8B	Oars, ash	Leathered and unleathered, 8 ft. to 20 ft. long, in sizes increasing by 1 ft. 12 ft. leathered for pontoons	
29C	Pontoons, bipartite, Mk. III ...	Bow and stern pieces ; 1,008 lbs. a pair	
29C	Ribands, wood	15 ft. 9 ins. by $3\frac{1}{2}$ ins. by 6 ins. ; 79 lbs. ; can be used as baulks	
29C	Sticks, rack	With 6 ft. of 2-in. lashing ; $1\frac{3}{4}$ lbs. ...	
29C	Transoms, shore end, Mk. II ...	11 ft. 5 ins. long ; 73 lbs.	
29C	Trestles, bridging, Mk. IV ...	Without 2 tackles, differential, 10 cwt. ; weight, 816 lbs.	

For lashings and wire rope, *see* Tables 10 and 12.

TABLE 12.—*Wire and wire rope.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
8A	Rope, galvanized, steel wire ...	In coils of 100 fms.	Fms.

Section in Vocab. of Stores.							
8A	Sizes, circumference, inches	3	$2\frac{1}{2}$	2	$1\frac{1}{2}$	$1\frac{1}{4}$	1
	Approx. weight, lbs. per fm.	7	$4\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{3}{4}$	1	$\frac{3}{4}$
	Safe load ($9c^2$) cwt.	81	56	36	20	14	9

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
29C	Rope, steel, ·65-in.	Breaking strain not less than 2 tons	100 yds.
3	Wire, galvanized iron, No. 14 S.W.G.	In 28-lb. and 56-lb. coils	Coil.
3	Wire, barbed	No. $12\frac{1}{2}$ S.W.G. 130 yds. 28 lbs. net a coil. 14 S.W.G. 165 yds. 28 lbs. net a coil.	,,
29D	Wire, entanglement (French) ...	One coil = 29 ft. In bundles of 5 coils and approx. $19\frac{1}{2}$ lbs. each coil. Staples in boxes containing 300.	,,
	Wire netting	3 ft. wide, in rolls containing 50 yds....	Roll.
29D	Expanded metal	Sheet 6 ft. 6 ins. long by 3 ft. wide. In cases of 20 sheets	Sheet.

Appendix VII—*continued.*

Table 12—*continued.*

The table below gives the properties, weight, &c., of new iron wire. New steel wire may be taken as twice the strength given, otherwise similar in size, &c.; galvanized wire is heavier.

Size, S.W.G.	1	2	3	4	5	6	7	8	9	10	11	12	13
Diam., inches ...	·300	·276	·252	·232	·212	·192	·176	·160	·144	·128	·116	·104	·092
Yards, per cwt.	155	183	220	260	311	380	452	546	675	854	1040	1293	1653
Lbs. per mile ...	1268	1073	895	758	633	518	436	369	292	231	190	152	119
Approx. breaking strain, lbs. ...	3804	3219	2685	2274	1899	1554	1308	1080	876	693	570	456	357

Size, S.W.G. ...	14	15	16	17	18	19	20	21	22	23	24	25	26
Diam., inches ...	·080	·072	·064	·056	·048	·040	·036	·032	·028	·024	·022	·020	·018
Yards, per cwt.	2186	2699	3416	4462	6073	8745	10796	13663	17846	24290	28908	34978	43184
Lbs. per mile ...	90	73	58	44	32·5	22·5	18·2	14·4	11	8·1	6·8	5·6	4·6
Approx. breaking strain, lbs. ...	270	219	174	132	98	68	55	43	33	24	20	17	14

Table 13.—*Bolts, dogs, nails and spikes.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
10	Bolts, with nuts, hexagon head	Principal store sizes: length and diam. in inches: 14 × 1 or ¾, 12 × ¾, 8 × ¾, 6 × ⅝ or ½, 5 × ⅜. Other sizes prepared as required	
N.I.V.	Bolts, drift	¾ in. × 24 ins. and ⅝ in. × 20 ins.	
28C	Dogs, railway and sawyers, Mk. III	Straight, 18, 15, 12 and 9 ins. long, with 9, 7, 6 and 4 in. spikes, respectively.	
10A	Nails, iron, spike (*quote store No.*)	Length, inches—: 10, 9, 8, 7, 6, 5 Nails in 1 cwt. (approx.):— 114, 155, 193, 294, 430, 590 Army Store No.:— *187*, *186*, *185*, *184*, *183*, *182*	lb.
10A	Nails, wire, iron, grooved	Length, ins.: 6, 5, 4, 3, 2½, 2, 1¾, 1½, 1¼, 1 Nails in 1 lb (approx.):— 14, 20, 30, 52, 100, 122, 200, 300, 400, 800	lb.
10A	Staples, No. 8 S.W.G.	Approximately 50 for each lb.	,,

APPENDIX VII—*continued.*

TABLE 14.—*Water supply stores.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
N.I.V.	Bends, elbows, tees, connectors, reducing sockets, cross-pieces, plugs, caps, nipples, back nuts, screwed flanges	For pipes of sizes as below	
N.I.V.	Cocks, stop	For $1\frac{1}{2}$ and 1-in. pipes	
N.I.V.	,, bib...	For 1 and $\frac{3}{4}$-in. pipes	
29E	Hose, canvas	2 ins. diameter in 20, 30, 50 and 100 ft. lengths	Lengths
29E	Hose, prepared, canvas, $1\frac{3}{4}$ in....	In lengths 6, 12, and 20 ft.	,,
29E	Hose, canvas, 2-in. bore... ...	For delivery only in lengths 20, 30, 50 and 100 ft. with "P" Mk. II unions, canvas or leather sleeves and strap, for lift and force; 2 in. semi-rotary; and portable, steam, Nos. 1 and 2 pumps; and for branching from water-pipes generally	,,
29E	Hose, rubber, $1\frac{3}{4}$-in. bore ...	In 6, 12 and 20 ft. lengths, with "P" Mk. II unions, wired in for use with lift and force, 2-in. semi-rotary, and portable, steam, Nos. 1 and 2 pumps, and "Blowers, rotary, Mk. VI."	
12	Pails, iron, galvanized	3 and 4 gallons	
7	Pipe-cutters	For sizes of pipe as below	
N.I.V.	Pipe, wrought iron, galvanized...	In sizes 6, 4, 3, 2, $1\frac{1}{2}$, 1 and $\frac{3}{4}$ ins. internal diameter	Ft. run
29E	Pumps, chain, helice	For hand only	
29E	Pump, lift and force, Mk. V ...	To lift 60 ft., single barrel horizontal gunmetal with handle. "D" Caps, Mk II, to suction inlet and delivery outlet; about 48 ft. suction hose and 30 ft. delivery hose with strainer and 2 hose wrenches "P" Mk. II. Weight, 88 lbs.; with hose strainer handle and wrenches, 228 lbs.	
29E	Pumps, portable, steam ...	Vertical, Merryweather's "Valiant" No. 1, for raising 3,000 galls. an hour against 150 ft. head with 15 ft. suction hose	
7	Stocks and dies, sets	For 4, 3, 2, $1\frac{1}{2}$, 1 and $\frac{3}{4}$-in. pipes ...	Set.
N.I.V.	Tanks, iron, galvanized, rectangular	In sizes from 20 to 1,000 gallons ...	
N.I.V.	Tanks, steel, corrugated, galvanized, circular	25, 50, 100 to 1,000 gallons; with taps and covers.	
2A	Tanks, waterproof, 2,300 gallons open	16 ft. 9 ins. by 16 ft. 9 ins. with stores, see M.E., Vol. V.	
2A	Tanks, waterproof, 1,500 galls., closed	Octagonal; no extra stores required	
2A	Troughs, waterproof, 600 gallons	With standards, 10 to a set, to water 16 animals at one time	Sets.
N.I.V.	Valves, air, sluice or reflex ...	For 6, 4, and 3-in. pipes	
N.I.V.	,, ball, stop or reflex ...	For 2-in. pipes	
N.I.V.	,, ball	For $1\frac{1}{2}$ and 1-in. pipes	
7	Wrenches, pipe, flat link ...	For sizes of pipe as above	

APPENDIX VII—*continued.*

TABLE 15.—*Demolition stores.*

Section in Vocab. of Stores.	Designation.	Detail.	How issued.
		BULK EXPLOSIVES.	
N.I.V.	Ammonal	Packed in 25-lb. and 50-lb. waterproof tins. Dimensions :— 25-lb. tin, $6\frac{3}{4}$ by $10\frac{7}{8}$ by $10\frac{7}{8}$ ins. 50-lb. tin, $13\frac{1}{4}$ by $10\frac{5}{8}$ by $10\frac{5}{8}$ ins.	Tins.
N.I.V.	Dynamite ... ... Blasting gelatine ...	Not an ordnance store, but, as a rule, obtainable from this source ; manufactured in various grades and strengths, usually in 2-oz. cartridges packed in boxes of 5-lbs. and 50-lbs.	Lbs.
25	Gun-cotton, wet, slabs, field, 1 lb.	Slabs 6 by 3 by $1\frac{1}{4}$ ins., 1 perforation for 1-oz. primer ; packed in waterproof boxes containing 14 slabs	Lbs.
		AUXILIARY EXPLOSIVES, &c.	
29D	Bags, gun-cotton, waterproof ...	Canvas 5 and 25 lbs.	
28B	Cable, electric, E_1, Mk. II ...	For electric firing ; weight 5·7-lbs. for each 100 yds.	Yards
N.I.V	Caps, copper, blasting. (Commercial caps)	The commercial equivalent of the No. 8 detonator ; manufactured in eight standard strengths, sizes 3 to 10	
26	Detonators No. 8, Mk. VII ...	For use with safety and with detonating fuze ; packed in tins of 25	
26	Detonators, electric, No. 13, Mk. III.	For use in electric firing ; packed in tins containing 25 detonators and a rectifier.	
28B	Exploders, dynamo	For firing charges electrically ; size $13\frac{1}{2}$ by $8\frac{1}{4}$ by $6\frac{1}{4}$ ins. ; weight 27-lbs.	Each.
26	Fuze, safety, No. 11	In tin cylinders of 8, 24 or 50 fathoms	
26	Fuze, instantaneous detonating	Wound on drums	Yards.
26	Fuzes, electric, No. 14, Mark III	For use with low explosives fired electrically ; packed in tins of 25	
25	Gun-cotton, dry, primers, field, 1-oz.	Packed in sealed tin cylinders containing 10 primers	
26	Matches, vesuvian	Fuzees ; 20 in a box	
		TESTING APPARATUS, ELECTRIC FIRING.	
29A	Boxes, testing and jointing, filled	Tin box in leather cover ; size 14 by 8 by $5\frac{1}{2}$ ins. ; weight 12-lbs. 3-ozs. : the contents are as follows :— For testing :— 1 box of resistance coils (100 ohms) 1 "Q" and "I" detector ... 1 cell, electric, dry, "E" ... 2 dwts. of iridio-platinum wire on 8 metal reels 1 chamois leather ... ... 1 box of plate powder ... For jointing :— ... 1 pair 5-in. side-cutting pliers ... 2 tubes of india-rubber solution ... 4 cylinders of india-rubber tape... $\frac{1}{4}$-lb. of cotton waste	

APPENDIX VIII.

Tables giving Stresses in, and Sizes of Ropes, Spars, Scantling, Girders and Rails for Use in Simple Field Structures.

1.—Stresses in derricks, sheers and gyns.

2.—Sizes of spars and baulks for derricks, &c.

3.—Tackles.

4.—Power required on falls of tackles in tons.

5.—Sizes of road-bearers and beams for light bridges, dug-outs, &c.

6.—Safe nett distributed loads in lbs. which can be supported by girders or rails over different spans.

Table 1.—*Stresses in derricks, sheers and gyns.*

(Stresses are stated in terms of weight to be lifted. Allowance has been made for weight of tackles, &c.)

Standing Derrick.		Sheers.	
Spar	2·0 W	Leg with leading block	1·2 W
Back guy	·7 W	Other legs	1·0 W
Other guys	·3 W	Back guy	·7 W
Gyn.		**Swinging Derrick**	
Spar with leading block	·6 W	Upright spar	2·2 W
Other spars	·4 W	Swinging arm	1·4 W
		Struts	1·0 W
		Connecting tackle	1·6 W
		Guys	1·25 W

In the case of the swinging derrick, the length of the upright spar and the swinging arm are assumed to be about equal and the angle between them not greater than 75 degrees. Any alteration in these proportions will affect them. The sizes of spars and guys can be found from Tables 2 and 3.

This table gives the maximum stresses which are likely to occur in practice, for the ordinary conditions under which these appliances are used. In special cases the stresses should be worked out graphically.

Appendix VIII—*continued.*

Table 2.—*Size of spars and baulk for derricks, trestle legs, &c.*

Mean diameter of spar in inches.	Length of spar in feet from point of attachment of main tackle to the ground. 5	10	15	20	25	30	35	40	45	50	55	60	Size of square baulk in inches.
6	4	1¾	⅝	—	—	—	—	—	—	—	—	—	5½
7	6	2¼	1¼	¾	—	—	—	—	—	—	—	—	6
8	10	4	2	1¼	¾	½	—	—	—	—	—	—	7
9	15	6	3	1¾	1¼	¾	½	—	—	—	—	—	8
10	20	8	4½	2½	1¾	1¼	⅞	⅝	½	—	—	—	9
11	26	12	6½	4	2½	1¾	1¼	1	¾	½	—	—	10
12	33	16	9	5½	3½	2½	1¾	1½	1	⅞	—	—	11
13	41	20	12	7½	5	3½	2½	2	1½	1¼	1	—	11½
14	50	26	15	10	6½	4¾	3½	2¾	2¼	1¾	1	—	12½
15	—	33	20	12½	8½	6½	4¾	3½	3	2½	1½	1½	13½
16	—	40	25	16	11	8	5¾	4½	3½	3	2½	2¼	14½
17	—	50	30	20	14	10	7¼	5¾	4½	3¾	3	2¾	15
18	—	—	36	25	17	12	9	7	5¾	4¾	4	3¼	16
19	—	—	43	30	20	15	11	8½	7	6	5	4¼	17
20	—	—	50	35	24	18	14	11	8	7	6	5	18
Inches.	Safe load in tons.												Inches.

This table is derived from Gordon's Formula $P = \dfrac{rA}{1+a\left(\dfrac{l}{d}\right)^2}$

where A = *sectional area in square inches.*
d = *least diameter in inches.*
l = *length of spar in inches.*
P = *safe working load in pounds.*
r = *safe compression stress in lbs. per sq. inch (1,000 lbs. per square inch).*
a = *1/48 for round and 1/62 for squared timber.*

Appendix VIII—*continued.*

Table 3.—*Tackles.*

Minimum size in inches of unselected cordage and steel wire rope to be used in main lifting tackles with leading block. The figures are illustrated on Plate **96**.

Weight to be lifted in tons.	Type of tackle and theoretical gain of power.					
	Fig. 4. W=P	Fig. 3. W=2P	Fig. 5. W=3P	Fig. 6. W=4P	Fig. 8. W=5P	Fig. 9. W=6P
	Cordage.					
¼	2½	2	2	—	—	—
½	—	2½	2½	2½	2	2
¾	—	—	3	2½	2½	2½
1	—	—	—	3	3	2½
1½	—	—	—	—	—	3
	Steel Wire Rope.					
1	2	1½	1½	1	1	1
1¼	2	1½	1½	1½	1	1
1½	2	1½	1½	1½	1½	1
2	2½	2	1½	1½	1½	1½
2½	3	2	2	1½	1½	1½
3	—	2½	2	2	2	1½
4	—	2½	2½	2½	2	2
5	—	3	2½	2½	2	2
8	—	—	3	3	2½	2½
10	—	—	—	3	3	3
11	—	—	—	—	3	3
12	—	—	—	—	—	3
Tons.	Inches.					

This table is derived from the formula $P = \frac{W}{G}(1 + fn)$, where P = power required to lift the weight, W = weight to be lifted, G = theoretical advantage or number of returns at the movable block, f = co-efficient of friction and n = total number of sheaves required.

If $f = 1/8$ (an average value) then $P = \frac{W}{G}\ (1 + \frac{n}{8})$.

The safe stress in cordage has been taken as $\frac{c^2}{20}$ tons, and if steel wire rope $\frac{9c^2}{20}$ tons.

APPENDIX VIII—*continued.*

TABLE 4.—*Power required on falls of tackles in tons.*

Size of rope.	Cordage.	Steel wire rope.
1¼-inch.	—	1 ton.
2 ,,	1/5 ton.	2 ,,
2½ ,,	1/3 ,,	3 ,,
3 ,,	½ ,,	4 ,,

Man-power equals a pull of 56 lbs. (1/40 ton) a man. Field capstan gives a gain of about 10 to 1.

TABLE 5.—*Sizes of road bearers and beams for light bridges, dug-outs, &c.*

1. Table showing the number of road bearers of different scantlings required for various spans.

Width of roadway has been taken as 9 feet, and the decking must be 3 inches thick.

—	Span in feet.					
	5	7	9	11	13	15
Scantling on edge (in inches).						
6 × 2	9	13	—	—	—	—
9 × 2	5	7	8	10	11	13
7 × 2½	6	8	10	12	—	—
6 × 3	7	9	11	—	—	—
8 × 3	5	6	7	8	10	11
9 × 3	5	5	6	7	8	9
4 × 4	10	—	—	—	—	—
5 × 4	7	10	12	—	—	—
7 × 4	5	6	7	8	10	11
9 × 4	5	5	5	6	6	7
5 × 5	6	8	10	12	—	—
7 × 5	5	5	6	7	8	9
9 × 5	5	5	5	5	5	6
6 × 6	5	5	6	8	9	10
8 × 6	5	5	5	5	6	6
8 × 8	5	5	5	5	5	5
9 × 9	5	5	5	5	5	5
Round poles aver. diam.						
5 inches	9	12	—	—	—	—
6 ,, ...	6	8	10	12	—	—
7 ,, ...	5	5	7	8	9	11*
8 ,, ...	5	5	5	6	7	8
R.S.J. (in inches).						
5 × 3 or larger	5	5	5	5	5	5
4 × 3	5	5	5	5	6	7
4 × 1¾	5	6	8	10	11	—
3 × 3	5	5	6	7	9	10
3 × 1½	7	10	—	—	—	—
20-lb. Decauville rail	6	8	10	12	—	—
80-lb. rail	5	5	5	5	5	5

* Where there is more than one 15-ft. span eleven 7-in. poles cannot be placed on the transom.

APPENDIX VIII—*continued*.

This table is calculated for a working stress in timber of ½ ton a square inch, and in steel of 7½ tons a square inch, and allows for a maximum moving load of 2 tons on one axle (i.e., infantry in fours or any horse transport load with a division).

The following is a simple rough formula for finding the safe working load for a beam of **unselected** timber, supported at each end :—

$$W = \frac{bd^2}{L} \text{ for a rectangular beam.}$$

$$W = \frac{6}{10} \times \frac{d^3}{L} \text{ for a round spar.}$$

And for cantilevers :—

$$W = \tfrac{1}{4} \times \frac{bd^2}{L} \text{ for a rectangular beam.}$$

$$W = \tfrac{1}{4} \times \frac{6}{10} \times \frac{d^3}{L} \text{ for a round spar.}$$

Where b = breadth of beam in **inches**.
d = depth of beam, or diameter of round spar, in inches.
L = span in feet.
W = safe distributed **dead** load in cwts.

This formula gives a factor of safety of about 4 and allows for superstructure weighing up to 1/6 W.

A **concentrated** load is a load which brings all its weight on one point on the bridge, *e.g.*, the wheels of a gun.

A **distributed** load is a load the weight of which is spread over a bridge, *e.g.*, infantry in fours.

A **live** load is a load that moves ; a **dead** load is a load that does not move.

i. To convert *live* load into *dead* load, multiply the live load by 1½.

ii. To convert *concentrated* load into *distributed* load, multiply the concentrated load by 2.

2. To use the above table for beams for dug-out roofs, divide 16,000 lbs. by the number given in the table for the scantling or pole at the required span. The result gives the safe distributed load in lbs. which can be carried by one beam. Then proceed as in Table 6. Example :—9-inch by 3-inch joists will safely carry $\frac{16,000}{5} = 3,200$ lbs. for each beam in a roof of 7-foot span, 5 being the figure given in the table for 9-inch by 3-inch timber over a span of 7 feet.

APPENDIX VIII—*continued.*

TABLE 6.—*Safe nett distributed loads in lbs. which can be supported by girders or rails over different spans.*

(If the load is concentrated in the middle of the girder or rail only half these loads are safe.)

Span in feet.	8-in. × 4-in. "I" girder, weight 18 lbs. a ft.	5-in. × 3-in. "I" girder, weight 11 lbs. a ft.	40-lb. steel rail, weight 13⅓ lbs. a ft.	60-lb. steel rail, weight 20 lbs. a ft.	80-lb. steel rail, weight 26⅔ lbs. a ft.
4	37,500	12,700	9,720	17,770	26,800
5	30,000	10,150	7,775	14,200	21,450
6 ...	25,000	8,440	6,480	11,500	17,875
7	21,400	7,200	5,550	10,150	15,320
8	19,900	6,300	4,860	8,880	13,400
9	16,600	5,600	4,320	7,890	11,900
10	15,000	5,000	3,890	7,100	10,725
11	13,500	4,600	3,530	6,460	9,750
12	12,500	4,200	3,240	5,900	8,940

The weight for each foot run is given for purposes of comparison. Thus, the 8-inch by 4-inch girder weighing 18 lbs. a foot is the most suitable for roofs of dug-outs, and is twice as strong as a 60-lb. rail weighing 20 lbs. a foot.

Steel rails are described by their weight for each yard, and may be recognized by their measurements:—

40-lb. rail is 3½ inches high.
60-lb. rail is 4¼ inches high.
80-lb. rail is 5 inches high.
Other weights in proportion.

To find the weight of earth in lbs. which is supported by one girder, multiply the span in feet by the distance apart of the girders in feet by the depth of earth in feet by 100 (a cubic foot of earth weighs roughly 100 lbs.).

To find the suitable spacing for the girders of a roof. Take the weight of 1 foot width of roof, and compare with the table above.

Thus for the roof illustrated on Plate **147**, the weight of one foot width of roof will be 9 (span in feet) × 8½ (depth of roof covering in feet) × 100 = 7,650 lbs., and if 8-inch by 4-inch girders are used a suitable spacing will be $\frac{16,600}{7,650}$ feet, or approximately 2 feet centre to centre. If 5-inch by 3-inch girders are used $\frac{5,600}{7,650}$ will be the safe spacing, or approximately 9 inches.

The following is a simple formula for finding the safe working distributed load for rolled steel joists (I girders) supported at each end:—

$$W = \frac{100\ bdt}{L}$$

And for cantilevers:—

$$W = \frac{25\ bdt}{L}$$

APPENDIX VIII—*continued*

Where b = breadth of the girder in inches.
d = depth of the girder in inches.
t = average thickness of one flange of the girder in inches.
L = span in feet.
W = safe distributed dead load in cwts.

For field bridges to allow for the loads being live (*i.e.*, moving) a rolled steel joist can only safely bear two-thirds of what it would take if the load was dead.

Example i.—What distributed live load will a rolled steel joist 9 inches by 4 inches with an average thickness of one flange $\frac{1}{2}$ inch, take over a 10-feet gap?

W (The safe distributed dead load in cwts.)

$$= \frac{100\ 4\ 9\ \frac{1}{2}}{10} = 180 \text{ cwts.}$$

Therefore the safe distributed live load it will take

= two-thirds of the safe distributed dead load.
= two-thirds of 180 = 120 cwt.

Example ii.—What size of rolled steel joist is required to carry a distributed live load of 60 cwts. over a 10-feet gap?

The safe distributed live load = two-thirds safe distributed dead load.

∴ 60 = two-thirds safe distributed dead load.

$$\therefore \text{Safe distributed dead load (W)} = \frac{60 \times 3}{2} = 90.$$

Substituting in the formula

$$90 = \frac{100\ b.d.t.}{10}$$

$$b.d.t = 9.$$

∴ A rolled steel joist with $b = 3$ inches, $d = 6$ inches and $t = \frac{1}{2}$-inch, will do.

APPENDIX IX.

Tables of Weights and Measures.

Table—

1.—Linear measure.
2.—Square measure.
3.—Cubic measure.
4.—Liquid measure.
5.—Measures of weights.
6.—Areas and contents of certain figures.

Table 1.—*Linear measure.*

	Ins.	Ft.	Yds.	Pls.	Chs.	Furs
Foot	12	1				
Yard	36	3	1			
Rod, pole or perch	198	16½	5½	1		
Chain	792	66	22	4	1	
Furlong	7,920	660	220	40	10	1
Mile	63,360	5,280	1,760	320	80	8
Fathom	72	6	2			
Nautical or geographical mile ...	72,960	6,080	2,026⅔			
Cable's length	7,296	608	202⅔			
Millimetre	·039	·003	·001			
Centimetre	·394	·033	·011			
Decimetre	3·937	·328	·109			
Metre	39·37	3·28	1·094			
Kilometre	39,370·79	3,280·90	1,093·633			

1 kilometre is approximately ⅝ mile; to convert miles to kilometres multiply by 1·609.

To convert yards to metres multiply by ·914.

Table 2.—*Square measure.*

	Ins.	Ft.	Yds.	Pls.	Chs.	R.	A.
Square foot	144	1					
Square yard	1,296	9	1				
Rod, pole or perch ...	39,204	272¼	30¼	1			
Square chain	627,264	4,356	484	16	1		
Rood	1,568,160	10,890	1,210	40	2½	1	
Acre	6,272,640	43,560	4,840	160	10	4	1
Square mile	—	—	3,097,600	102,400	6,400	2,560	640
Centiare	1,550·059	10·764	1·196				
Are (100 sq. metres) ...	—	1,076·430	119·603	—	—	—	·025
Hectare	—	—	11,960·333	—	—	—	2·471

To convert acres to hectares, multiply by ·405.

APPENDIX IX—*continued.*

TABLE 3.—*Cubic measure.*

1,728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.
1 cubic metre = 35·3156 cubic feet.

To reduce cubic feet to cubic metres, multiply by ·028.
1 cubic foot of fresh water weighs 1,000 ozs., or 62½ lbs.
1 cubic foot of fir weighs 40 lbs. approximately.
1 cubic foot of oak weighs 59 lbs. approximately.
1 cubic foot of beech weighs 43 lbs. approximately.
1 cubic foot of earth weighs 80 to 100 lbs. approximately.
1 cubic foot of brickwork or concrete weighs 120 lbs. approximately.

TABLE 4.—*Liquid measure.*

	Pints.	Quarts.	Gallons.
4 gills	1	—	—
Quart	2	1	—
Gallon	8	4	1
Firkin	72	36	9
Kilderkin	144	72	18
Barrel	288	144	36
Hogshead	432	216	54
Puncheon	576	288	72
Butt	864	432	108
Litre	1·759	·880	·22
Hectolitre	175·976	87·988	21·997

To convert gallons to litres, multiply by 4·56.
A gallon of fresh water weighs 10 lbs.

TABLE 5.—*Measures of weights.*
(Avoirdupois weight.)

	Ozs.	Lbs.	Qrs.	Cwts.	Grains.
16 drachms	1	—	—	—	= 437·5
Pound	16	1	—	—	=7,000
Stone	—	14	—	—	—
Quarter	—	28	1	—	—
Hundredweight	—	112	4	1	—
Ton	—	2,240	80	20	—
Gram	·035	·002	—	—	—
Kilogram	35·26	2·204	—	—	—

To convert lbs. to kilograms, multiply by ·454.

TABLE 6.—*Areas and contents of certain figures.*

Circle radius $(r) = \frac{1}{2}$ of diameter (d).

circumference $= 2\pi r = \pi d. \quad \pi = 3\cdot14159$ or $\frac{22}{7}$ nearly.

area $= \pi r^2$.

Triangle area $= \frac{1}{2}$ base $\times$ perpendicular from apex to base.

Cylinder of height h — content $= \pi r^2 h$.

Cone of height h — content $= \frac{1}{3}\pi r^2 h$, $r =$ radius of base.

Pyramid of height h — content $= \frac{1}{3}h \times$ area of base.

APPENDIX X.

INSTRUCTIONS ON THE USE OF CAMOUFLAGE.

1. *General principles.*

1. *The aim of camouflage.*—Concealment in the sense of hiding an object from view, is by no means the primary aim of camouflage. For example, if you hide a gun under a tarpaulin it is concealed, but it is also certain that the weapon is not camouflaged in the true sense of the word.

A hare lying up in the furrow of a ploughed field is perfectly camouflaged by nature; though in reality it is visible, it is not distinguishable.

Deception is the essence of true camouflage.

2. *Air observation.*—Air reconnaissance played an ever-growing part in the Great War, and it is safe to predict that with the knowledge gained, and the improvements which are bound to be effected in the construction of aircraft combined with the results of photographic research, observation from the air will dominate all other methods in the future.

Reconnaissance from the air consists of visual and photographic observation.

In rapidly moving warfare photography is confined more to the back areas and is of the greatest assistance in penetrating the mind of the enemy by piecing together fragmentary proofs of the movements of troops and war material by night as evinced in new structures and shapes on the landscape all peculiar to warfare and each having a meaning.

In position warfare the conditions conduce to the collection of a great mass of photographic evidence over all areas, which can only be nullified by an advance.

3. *Importance of photography.*—The great improvements effected in the construction of cameras, lenses, and plates combined make it by far the most reliable medium for recording air observation.

A photograph taken under favourable conditions in $\frac{1}{125}$ of a second, discloses more information than an observer will be able to report after a long flight. The keenest and most receptive mind cannot possibly compete with it.

The laws governing stereoscopic photography are adaptable to air reconnaissance with the camera, and it is possible to obtain exaggerated relief of small objects.

It must be remembered that the camera generally accentuates any contrast in the tone of an object as well as its shadow, so that it seems to throw into relief what would appear an inconspicuous thing to the observer.

The chief energies of the camoufleur must be directed against the camera.

4. *Form.*—The form of any object is built up of varying planes of light and shade. On a dull day the diffused illumination from above is sufficient to disclose form to the ground observer, but makes it more difficult to read in an air photograph taken more or less vertically. Such a photograph gives little idea of the height of objects. Under such conditions, photographs taken stereoscopically are of great assistance and give the relief necessary to form an estimate.

A good photograph taken in the early morning or late afternoon will often reveal more than stereoscopic photographs taken vertically in a diffused light.

The elongation of shadows shows better than anything else the relative heights of buildings, ruins and contours.

Such photographs should not be relied upon to give the character of a building with exactitude, unless the ground in the vicinity is fairly flat. If broken, undulating, or hilly, there will be a certain amount of distortion of the shadows.

The presence of an object having been revealed, its shape should be determined with the aid of another photograph taken when the sun is not so low. The experienced reader will be able to see many revelations not apparent to the lay mind in these distortions.

When an air photograph is being studied it should be placed so that the light, whether natural or artificial, falls from the same direction as it did in nature, *i.e.*, if a photograph is taken at midday and examined at a table with the window on the left, the east side of the photograph should be held towards the window. If held the reverse way, with the west side towards the window, hollows will become mounds and embankments appear as cuttings.

5. *How objects photograph.*—The various colours and textures of nature are interpreted in the photograph by tones all having relative values. Texture plays the most important part in determining tone. Colour is a secondary consideration.

A smooth white surface will photograph white, but a textured white surface will be recorded a lower tone owing to the innumerable shadows contained. Similarly a smooth black surface will be a lighter tone than a textured black surface which will photograph black.

It follows, therefore, that the most effective medium to obtain a certain required tone is a textured surface.

Plate 178 illustrates tone values of various surfaces found on a landscape.

A careful study should be made of the structure of gorse as it will help considerably towards a better understanding of the underlying principle of the creation of tones.

In gorse the aggregation of reflecting planes is small compared to its area. It contains deep shadows, and as will be seen in the above-mentioned plate, it photographs a very dark tone.

A fallacy often repeated is that long grass invariably photographs a very dark tone. This statement must be qualified. Long grass growing upright will be recorded a dark tone owing to the innumerable shadows contained within its area, but should the grass be very long and consequently leaning over, it is obvious that it must be reflecting a great amount of light. Therefore it will be a lighter tone than grass a few inches high standing up stiff.

Consequently when estimating the tone of any growth of vegetation it will be necessary to consider the shadows and the amount of soil to be seen when standing over it. In other words the thickness of the growth has to be taken into account.

Most trees, having a greater surface of reflecting planes relatively, photograph a lighter tone than gorse.

6. *Use of colour.*—Colour can be of great service if used with a full knowledge of its photographic value and its impression on an airman optically. It is generally well known that the higher one flies the less pronounced becomes any optical contrast in colours, until at a few thousand feet the landscape becomes a study in monochrome. Detection of differences in colour is therefore difficult at high altitudes.

Plate 179 shows a tone chart of colours as rendered by the plate used generally in air photography. It will be seen that the red tone approximates to that of blue.

Now it would be a most dangerous thing to use red in a scheme of camouflage that is intended to imitate a blue background. It would defeat the camera if the texture were correct, but it would surely attract the attention of the airman if flying low.

To attain the best results in imitative work it may be taken as a general rule that the selection of colour should be considered with choice of texture.

7. *Meaning of tone.*—Tone is the value of a colour rendered in a shade of black and white. Colour can influence the tone of a surface, but not to the degree of certainty obtained by the use of texture.

A smooth surface painted black, when viewed from certain angles, will appear black and photograph so, but there is a great risk of reflection of light at other angles which makes the use of paint not only an uncertain but even a dangerous medium in the creation of tones. It could be relied upon to give better results in diffused than in brilliant light. A good matt black will be more certain in its effects on the photographic plate.

8. *Nature's patterns.*—In nature all forms and patterns are irregular. Regularity in a landscape is always the work of man. In camouflage it should be borne in mind that highly finished details which may be almost perfect reproductions of nature when viewed closely are entirely lost when observed from the distance at which air photographs are taken.

The work should be broad and the introduction of details resorted to only when the subject demands it, such as the outline of a chimney on a house. Lesser features should be suggested on the drawing.

Camouflage patterns should be on a large scale. The multiplicity of small patterns on a painted area will disclose the form, and is useless if the intention is to distort it.

2. *Materials.*

1. *General.*—A thorough knowledge of the materials used in camouflage is essential in order that by employing each article in the right place the greatest and most economical use may be obtained, and the most efficient method of concealment achieved.

The problem of camouflaging a position or object must be most carefully considered in every aspect. If the wrong material is used, the scheme is doomed to failure; moreover bad camouflage advertises itself, and the enemy will assume that, as attempts have been made to hide something, important organizations are close at hand.

In all schemes it must be remembered that artificial camouflage should not be employed unless the immediate surroundings absolutely demand it. In many cases far better concealment can be obtained, without employing artificial fabric at all, by intelligent siting and clever adaptation of natural material.

The following fabrics and materials are employed in camouflage. These are classified under headings and short notes appended (*see* also Table 8 Appendix VII).

Fabrics.

2. *Canvas, hessian.*—Hessian canvas is closely woven and smooth in texture, it will therefore in its original state, when laid out in sheets, photograph light in tone. Hessian canvas has a smooth, light reflecting surface, and accordingly

should be used to imitate similar objects such as roads, tracks, or newly turned earth.

This canvas cut into strips 12 inches by 2 inches, treated with paint, and knotted or woven into a foundation of wire or fish netting is used as a cover in grass country. It may also be used attached to dead shrubs or trees, simulating living foliage and forming what is known as the "Hasty tree" device.

Water in shell holes can also be simulated by painting the canvas. Oil paint must be used.

3. *Canvas, scrim.*—Scrim canvas is very loosely woven and allows for greater absorption of light than hessian. This can be understood by examining a sample of scrim.

Large irregular patches of this material attached to wire or fish netting foundation, achieve the same photographic results as shell torn ground. With green canvas knots intermingled, the same result as badly shelled grass land is obtained.

Scrim is also employed to cover trenches, dumps, &c., and also to reduce reflection at night on the roofs of hangars or large buildings.

4. *Coir netting.*—This is an excellent medium for obtaining a very dark tone when used with black distemper.

5. *Gauze.*—Used for covering the apertures of observation posts, periscopes, snipers' posts and loopholes.

Any kind of background can be simulated on the gauze by painting. The painted gauze presents a seemingly opaque surface when reflecting light.

6. *Wire and fish netting.*—These are the foundation of practically all overhead covers. In wire netting, which is fire-proof, meshes between ¾ inch and 2 inches seem to be generally the most effective for flat topped covers. Fish netting is more portable, but inflammable.

Netting of a smaller mesh than 1½ inches makes the work of inserting strips very difficult.

Further trials with both wire and fish netting are being undertaken to ascertain definitely what size and arrangement of meshes are most effectual for flat-topped covers and for screening purposes generally.

Owing to its non-inflammability wire netting has a great advantage for artillery purposes, but, being heavier and less easily made up in loads than string netting, the latter may prove to be more generally suitable for mobile warfare. Wire netting should usually be painted.

7. *Expanded metal.*—Is used most frequently to conceal blast marks. It should be noted that one sheet of the metal photographs like sparse grass in tone, two sheets like fairly thick grass, and three sheets like very thick grass. There is no need to paint it.

8. *American cloth.*—There is only one use for this material. Hessian canvas, painted with oil paint to imitate water in shell holes, has already been mentioned. A still better way to simulate the appearance of water is to employ red american cloth. This has a glossy surface with a natural reflection, far superior to the dull canvas. The colour resembles dirty water.

Modelling Materials.

9. *Gesso.*—This is a plastic, weather-proof material used mainly for modelling observation posts and false parapets.

Its composition is of the following proportions :—

Glue	6 parts.
Boiled Oil	4 „
Resin	1 part.

These are boiled together and while hot, whitening broken up in water is added, and the whole stirred until the composition is in a thoroughly plastic, adhesive state.

The ground work for the model is usually wire netting. On this is placed canvas soaked in gesso, and on the gesso, earth, mud, sandbags, &c., are stuck and modelled as required.

10. *Paint.*—Distemper is used generally in camouflage work, but any other form of paint which dries with a matt surface may be used (*see* also Sec. 3 of this Appendix).

11. *Plaster, papier mache, cement and mastic.*—These are all used in the manufacture of portable loopholes, observation posts and trees, snipers' heads, animals, pillbox covers, and general modelling.

Mastic and tar are used to assist in the general application of texture to roofs, vertical sides of buildings, &c.

Constructional Materials.

12. *Wood posts.*—Are used as supports for overhead covers in conjunction with wire.

13. *Gas piping.*—Is used as framework for some types of covers. It is expensive but non-inflammable.

14. *T. and angle irons.*—Are used in construction of various devices employed.

Natural Materials.

15. *General.*—The importance of making use of natural materials cannot be too strongly emphasized. Indeed every effort should be made to include natural surroundings in all attemps to camouflage, remembering that it is not always possible to obtain artificial materials, which even if obtainable cost money, and require labour for their transport, which might be more profitably employed otherwise.

Too much reliance must not be placed upon articles of store, as in the event of their loss on active service they may never be replaced.

16. *Hay and grass.*—These are useful for threading into netting, and by such means a very good texture can be obtained. When painted it is very realistic and cannot be detected from the actual thing.

This kind of netting is useful for covering trenches, saps, and assembly trenches.

When netting is used to eliminate shadows, hay and grass knotted to it form projections which catch light and so break up the shadow.

17. *Tar.*—This used on smooth surfaces with hay added produces depth of tone.

18. *Bamboo.*—This can be made use of for light frame work where portability is to be considered, such as covers for machine guns.

19. *Branches and foliage.*—These are useful in the construction of what is called the "Hasty tree" device, also for covering the litter around gun

emplacements, thereby breaking up the identity of the objects which they are covering.

20. *Broken turf.*—Creates shadows in the sunlight, but it is well to remember that its use as a medium to create shadows is not very reliable, as on a grey day or when there is very flat lighting as at midday the contrast lessens. Under these conditions some artificial method should be employed such as black distemper.

21. *Sub-soil.*—It should always be remembered that sub-soil is different in tone from surface soil, and in all work of concealment great care should be taken to preserve the top soil and replace it with the last layer of earth when finished. Turf is the most satisfactory surface to replace, if the initial tone is required to be reproduced.

3. *Painting.*

1. Painting is chiefly an "anti-optic" medium but to a less degree "anti-camera." It is employed under the following aspects :—

   i. Vertical and oblique from the air.
   ii. Horizontal.

2. *Vertical and oblique from the air.*—It has been shown that painting on smooth surfaces against the camera is rather hopeless if unassisted by rough-textured material.

The general tone of the uncultivated landscape is dark and any light tone attracts the eye. Therefore the tone of things painted against the view from the air should be dark. It is possible by means of pigment to deceive the airman to a considerable extent, but his camera cannot be deceived. The colour schemes should be quiet. Glaring colours will attract attention at low altitudes and should be avoided.

3. *Horizontal.*—Much more successful results will be obtained from paint when it is used on objects to be seen from ground observation.

There are two problems to be considered :—

   i. The object to be painted for a fixed position.
   ii. The object to be painted for movement.

4. There are two methods of treatment :—

   i. *The scenic* which consists of painting a picture of the background on the object.
   ii. *The disruptive* which consists of painting in masses of contrasting colour in such a manner that the shape of the object is contradicted and thereby not recognized easily.

5. *Realistic painting.*—Scenic painting or deliberate imitation is most successfully employed on fixed objects which are close to a solid background.

   i. *Against sky.*—It is useless to paint objects with the idea of preventing their showing up against the sky. Paint is only of use in merging an object into a background. It will not reduce a silhouette except under perhaps one condition—namely, when the sun is shining on an object; but this is not constant.
   ii. *Against backgrounds.*—In this case there are two considerations :—
      The shape must not attract attention.
      The shape must be destroyed as much as possible.

(a) If the work is not to attract attention, the character of the setting must be studied and imitated closely. Bigness in design is essential. Small details are useless.

(b) To destroy the shape of the object the edges must be treated. Too large a quantity of light tone on the edges will give relief against a dark background and vice versa. Before treating the shadows the orientation of the painted object must be considered.

If the enemy is towards the east the object will appear in sunlight in the morning and in the shadow in the afternoon, so a compromise in the painting must be effected.

6. *Disruptive painting.*—This method is generally employed on objects not in proximity to a solid background or that are in motion. The design must be based on the nature of the surroundings and should be adjusted to contradict the shadow so as not to emphasize the shape. For example:—Horizontal and vertical masses should not be painted on a rectangular building except in special circumstances (*see* Sec. **11**, 2 of this Appendix and Plate **180**).

Masses with a diagonal tendency would be more suitable to the case if the background is appropriate. It would not do to paint one building forming part of a group in a disruptive manner to the exclusion of the others.

All under portions which are always in shadow should be painted light to neutralise the shadow. This counter-shading is to be found on most living animals. Those parts of the animal that are always in shadow are light-coloured. The depth of shadow is minimised. Moving objects should be treated with designs to contradict their shape. This is the most difficult branch of painting. The best disruptive pattern cannot conceal or camouflage movement, and it is well to remember that in nature protective patterns and colours are of the greatest use when the creature is at rest.

Patterns should be on a large scale; three masses are generally sufficient. They should offer strong contrast in colour, a dark tone dividing them helping to accentuate it. The colours used should be broad with a view to blending them with the local nature tints.

Designs must differ according to the surroundings. The details of this method of disruptive painting is largely a matter of common sense. Imagine a group of three huts in an open field. If the huts are small and placed close to each other, it would be futile to attempt to disrupt each hut. The group must obviously be treated as a whole, that is to say, the design must be carried through the group. The idea of vastness of design cannot be impressed too strongly.

7. *Brushes.*—Economy in the matter of brushes is an important thing. They are easily ruined by being left uncleaned after use. If there is no time to clean them, stand them in a bucket of water. This will prevent them getting dry and becoming useless for the next day's work.

8. *Paint formulæ.*—In the following table the numbers show the proportions by weight in which the dry pigments should be mixed before adding to a corresponding weight of the medium.

The medium is known as "mocha" and, as its composition shows, is a distemper:—

Water	1 gallon.
Size	1 lb.
Boiled Oil	½ pint.

These are boiled together the day before use and the pigments then added.

To imitate—	Use—	
Grass and other green foliage ...	Brunswick Green ...	6
	Yellow Ochre ...	5·5
Red Sand and Gravel	Yellow Ochre ...	6
	Venetian Red ...	0·015
Loam	Whitening	3
	Yellow Ochre ...	3
	Vegetable Black ...	0·2

9. For painting on metal, good results can be obtained by the use of ordinary oil paints mixed with fine material, such as sand, to give a matt surface.

4. *Application to tracks.*

1. *General.*—Tracks are the surest indications of activity and give more information regarding the movement of troops and war material than any other photographic sign (*see* Plate 181). By their aid it is possible to arrive at a fair idea of the dispositions of troops.

In position warfare it is even possible by studying the tracks made by reliefs to determine the distributions of battalions, brigades and divisions.

In mobile warfare, tracks are more numerous but not always so significant, and the photographic value is lost to a certain extent in so far as it affords any indication of the plan of the enemy.

The consideration of tracks, therefore, is connected more directly with the conditions obtaining in position warfare and becomes of vital importance to the numerically inferior force.

2. *Creation of tracks.*—In Sec. 1, 5, of this Appendix will be found the meaning of texture and its important role in the creation of tone values. It also shows that the quality of texture affects the resulting tone in varying degrees.

In the case of thickly growing grass the tone depends not only upon the density of the growth but also on its length. In regard to short grass the blades have a tendency to reflect light, but during growth they assume a more perpendicular position, which results in their containing more shadow.

Pressure on any part of such a field will cause the blades to be moved from the vertical into planes reflecting light. A succession of such pressures at regular intervals, although not seen from the ground, are connected up by the camera at an altitude of a few hundred feet, and seem to form in the photograph a continuous line.

3. *Prevention of tracks.*—The creation of a track is a very simple matter, much more so than its obliteration.

Frequent references are made in this Appendix to lines of demarcation on the landscape and the uses to which they can be can to suppress tracks. In this, as in all other problems of camouflage, it is essential that recent air photographs should be available when considering the siting of new works, no matter how unimportant they may seem. Intelligent use must also be made of any existing paths or tracks. It is desirable for all such ways to be wired off to confine men to them.

It is often very difficult at night for men to keep on one track, consequently unless means are taken to prevent it, the size of the roadway will rapidly increase. The fullest use must be made of existing roads at night, and of paths and tracks by day.

If, owing to their position, men have no access to a road or path, communication must be made in some way to prevent fresh tracks being made to important locations. In the event of the ground being broken up, there would be no harm in sending men in scattered formation across country to a rendezvous on a road. In order that this may be carried out successfully, the soldier's training must include exercises which will help to develop his sense of direction, especially at night.

Communication trenches reduce the number of tracks in the forward area, but it is remarkable how they increase immediately men are free from such confines. Each individual immediately proceeds to take his idea of the shortest way back.

In mobile warfare it is not necessary for men to take any particular care what tracks they make towards the front, and it cannot be expected of them to do so, since any observance of the rule would destroy their "elan" in attack.

When and where this rule of track discipline must apply depends on the rapidity of the advance or the possibility of a halt, and whether the battle front is likely to become stabilized. In back areas every endeavour must be made to deal efficiently with the problem.

A study of a photograph (*see* Plate 182) taken immediately after a battle will often show an area worn lighter than the rest of the ground, due to a stand made, but the innumerable tracks convey very little meaning beyond what could have been obtained by ground observation.

When the attack has finished, aircraft will immediately reconnoitre the back areas and take photographs. Accordingly the covering up of photographic evidence as to the movement of troops becomes more than ever essential.

If a track is through long grass it will alter in tone according to the time of day the photographs are taken. Such a track denuded of grass, running east to west, will photograph almost white in the morning and evening, but towards midday there will be a dark shadow obscuring part of the track. Under the same conditions cart tracks will be found to vary in tone in different lights.

These differences in the appearance of the same track in various photographs, or a combination of light and dark tracks in the one print, assist in deciding the state of the growth of the vegetation.

In muddy soil tracks are usually dark. This must be borne in mind when considering any plan of work on ground which would be of a light tone under normal circumstances.

The contrast of dark toned tracks on a light ground are quite as striking as the appearance of light tracks on a dark ground. A large, light area, churned up by many feet and wagons, if it be of a rectangular shape, will not be so suspicious as an irregularly shaped disturbance.

All positions should be sited with a view to the avoidance of tracks, and the fullest use should be made of ground features such as ditches, hedges, the boundaries of fields and buildings where they form a continuous cover or line of demarcation from a roadway.

A rectangular patch of earth can be operated upon so long as it is done evenly over the whole surface. The worst that can happen is an alteration in tone.

4. *Concealment.*—It is possible to conceal short lengths of track made to important positions by means of netting threaded with painted strips of canvas suitable to the tone of the locality, but no concealment should be attempted if there is any likelihood of the enemy having secured a photograph of the locality.

The eye should not be relied upon to judge such tone, but an air photograph should be secured and the degree of texture necessary to give the approximate tone can then be estimated much more easily.

As a rule, a thinly threaded overhead cover is dangerous, as the light tone of the track will always show through to some extent. A cover of this type, thickly knotted, placed immediately on the track gives a most satisfactory result, as the rough material casts shadows on the ground immediately adjacent to where it lies and ensures a dark tone being obtained.

The chief disadvantage of this method is that any continued traffic would gradually wear down the texture to a lighter tone. The best solution, if the material is available, is an overhead cover in addition to one placed directly on the track. If this is done the ground cover may consist of scrim painted with black distemper. The black must be renewed from time to time.

Care must be taken to select an overhead cover which would throw the minimum amount of shadow if the situation will not permit of the cast shadows of natural features being used in which to merge that of a thick cover.

It would be possible to lower the tone of the track by spraying it directly with the black distemper. This is a good plan if scrim is not available. In wet weather an extra supply of the distemper must be handy as the accumulation of mud would make the track lighter in tone.

5. *Use of tracks.*—In back areas much ingenuity can be exercised in the disposition of tracks to lead the enemy to false conclusions. An example is given in Plate 183.

It is not sufficient that tracks be made to lead the eye of the reader away from a vital position. They must lead to a logical point, that is to say, the continued tracks must have a meaning. If a diagonal course is taken across two or three fields on to a road without there being some visible reason, the idea is futile.

In reserve areas, where men are drilled and otherwise exercised, every opportunity should be seized upon to mislead the enemy in the matter of tracks. The means are at hand to carry out most elaborate deception.

Most countries have now gained much knowledge of this subject and in future warfare the avoidance of tracks will be of the first importance, consequently new paths and tracks will be looked upon with great suspicion unless there appears an excellent reason for their appearance.

6. *Track discipline.*—The maintenance of discipline in the field must be extended to include all traffic in so far as it includes the work of the camoufleur. It must be regulated in such a manner that disturbances to the ground tones are reduced to a minimum.

Wherever possible traffic must keep to the roads and when short cuts have to be made they must be done with full knowledge of the photographic result. Much can be done by lecturing men on this subject. Routes should be explained clearly before journeys are made off roads.

Existing paths and tracks may be used but their area must not be extended. A most common feature is the wearing of grass at the beginning of such tracks from the roadway. A few men using these tracks for a day or two will do the mischief.

A remedy is the erection of two thin stakes at the commencement of such tracks and instructions given to the men to pass between them. The same thing should be done at the other end if there are no other confines.

5. *Application to infantry organizations. Forward area.*

1. *Trenches and saps. Vertical observation.*—Owing to the more searching observation and consequent interruption to which work in the forward area is subject, it is impossible to carry out elaborate camouflage schemes which might be achieved in more favoured locations. It is obviously futile to attempt to hide an active front line trench, and, indeed, an impossibility to conceal a line of trenches from photographic reconnaissance, no matter where they may be. Although it is possible to break up a trench system the enormous amount of material needed, and the constant renovations necessary for the upkeep of the work, outweigh any advantage gained.

i. *Choice of site and intelligent use of background.*—Every endeavour must be made to utilise to the utmost any natural advantages, both in siting the trench and in the choice of background. The fullest use must be made of ditches, hedges and other pronounced lines of demarcation in considering communications and dug-outs.

Trenches following any such plan are not so conspicuous, and make it easier to simulate dummy works in a logical manner which will draw the fire of the enemy from the actual lines of communication.

ii. *Dummy trenches.*—Experiments have shown that between the months of October and March in northern latitudes, a dummy trench only 3 feet deep will be the same in all appearance as one 6 feet deep when photographed from the air at a height of 5,000 feet.

In summer or when the sun is at a high altitude there is a risk of such a dummy trench not containing a shadow.

At such a time a shadow must be created. This can be done by cutting down the thinner branches of any trees in the locality and placing them with the foliage intact on the bottom of the trench. Other mediums for creating the photographic tone of a shadow are gorse and brushwood. If available, coir netting dipped in black distemper may be successfully used to this end.

In mobile warfare or in the course of an offensive, after a period of position warfare, the hastily dug trenches seldom reach the depth to create a shadow. These must not be taken for dummy work.

iii. *Defended localities.*—In developing a trench line to form a system of defended localities, new work may be camouflaged by means of fish netting and knotted canvas. Use could be made of trees by removing their branches, stripping them and laying them across the trench. The netting should then be laid over the branches and the edges pegged down on each side of the trench. The netting must always be taut as any sagging will invariably reveal the outline of the trench.

iv. *Distribution of spoil.*—Concealed trenches should always be sited with due regard to the disposal of the spoil and use made of the lines of demarcation already referred to. In all cases where it has been decided to camouflage earthworks or even to commence any new work in the trench system, the

disposal of spoil is of vital importance. Many positions otherwise well camouflaged have been revealed by the thoughtless distribution of spoil.

In many cases it was considered sufficient to spread the excavated earth anywhere so long as it was kept under the overhead cover. No greater mistake could be made. The light tone of newly turned earth is accentuated by the plate used in air photography, and moreover, the cover itself, which thins out towards the edges is not sufficient to counteract the light tone of the earth beneath.

The only remedy is either to dispose of the spoil on a background already photographing light or to cover the earth over with turf or camouflage fabric.

Such backgrounds are:—

i. Fallow land.
ii. Ground where the grass has been worn.
iii. Plough.

The excavated matter must be scattered over the ground, care being taken to see that any tracks are subsequently obliterated. A course should be marked out for them over ground of a light tone. The tracks made by wheelbarrows must be flattened out from time to time.

2. *Trenches and saps. Horizontal observation.*—**Whenever feasible a fire trench should not be sited in such a position that the occupants' heads, when firing, are silhouetted against the sky or other light background.**

If, by force of circumstances, an unfavourable spot has to be deliberately selected, much can be done by seeing that the outline of the trench is irregular and arranging for the parados to act as a background behind any gap used by a man as a firing position.

Sometimes it may occur that the background which existed before the trench was dug, was more favourable to concealment than the newly excavated soil, especially with a chalk sub-sub soil.

The only remedy would be to simulate the chalk by tying pieces of it on to whitened sandbags after making provision for eyeholes and drawing the bags over the heads of the men.

Should the soil be earth or clay it may be taken as a general rule that some of the local mud rubbed over sandbags will make the most effective mask. With a grassy background, as in old trenches, it is harder to improvise any such device. Weeds or foliage could be tied on either to the sandbags or to the men's headgear, but this takes time which might not be available.

Snipers have better opportunities of making use of such protective devices, and they should realise the advantages and utilise them as much as possible.

In nature protective colours and patterns have the maximum effec when the object to be dealt with is at rest, and the background is appropriate.

A slight movement which would not be detected when an object has a suitable background would be visible if there were any great contrast in colour and pattern.

Horizontal movement should always be avoided. When raising the head to observe do not move either to the right or the left if the position is unsatisfactory. Withdraw slowly and move under cover to a more favourable spot.

3. *Snipers' loopholes and forward observation posts* :—

i. *The siting of snipers' loopholes.*—These may be sited in any position where there is command, however slight. It is not necessary to confine them to the front line. Favourable sites can often be found in the parados of the fire trench, in communication trenches, in no man's land and in the open in between the trench lines.

In siting a post an oblique line of fire will be found most advantageous. A position giving direct fire across no man's land is far more likely to be detected than one placed at an angle, owing to the greater display of the loophole.

Positions built in the parados of the fire trench should immediately be vacated when there is heavy firing owing to their exposed situation. Such positions have the advantage of a direct view over the parapet and the flash of the rifle is difficult to locate. In this case and also where the sniper has taken up his position in a communication trench it must be arranged that the portions of the fire trench crossed by his line of fire are evacuated.

ii. *The siting of observation posts.*—Although the primary object of an O.P. is to obtain an uninterrupted view of the objective, concealment, when situated in close proximity to the enemy, becomes of paramount importance. Every endeavour must be made to utilise to the utmost any natural advantages which may present themselves. **A located observation post speedily becomes untenable and a danger to the neighbourhood.**

iii. *Types of loopholes and observation posts.*—An adaptation of the Oliver O.P. shown on Plate **186** makes an excellent loophole. This enables the sniper or observer to obtain good command. It should be placed in position at night.

In placing the ordinary sniper's plate care must be taken to see that it is out of the perpendicular, as this gives greater resisting force to the bullet and increases the tendency for a ricochet.

Three types of O.P. are illustrated. They consist of a very light unarmoured, easily portable structure, termed the Beehive (Plate **184**); an armoured form which can be carried by two men without difficulty, called the Roland (Plate **185**); and a heavy structure, which requires a cabin as a foundation and takes several men to transport it in sections, named the Oliver (Plate **186**).

4. *Dug-outs.*—Coming under this heading the following are the most important :—

Company headquarters.
Battalion headquarters.
Advanced brigade headquarters.
Telephone exchanges.

i. The following points tend to disclose the position of these centres :—

(*a*) Accumulation of spoil.
(*b*) Tracks converging towards the dug-out.
(*c*) Buried cables and air lines.
(*d*) Regular shadows.
(*e*) The dark rectangular shadow of the dug-out entrance.

ii. *Method of siting.*—Bearing this in mind, the location of the dug-out should be such that the spoil can be easily distributed into old trenches, shell-holes, ruins or other features, without attracting attention.

Provision must be made for the additional traffic. Where the dug-out is situated in part of a trench system, the men must keep to the trenches and on no account take short cuts over the top. The entrance must be covered by canvas, or sandbags sewn together.

Where the dug-out is in the open, care must be taken in laying out ways of approach and departure. Full advantage must be taken of any natural features, tracks being kept under trees or along the north side of hedges in the shadow. Buried cables should take full advantage of the background, lines of demarcation between fields or hedges being followed.

5. *Consolidated shell-holes.*—Occupied shell-holes may be located usually by the following:—

Spoil.
Tracks linking up the line.
Regular lines and shadows caused by work.
Dark shadow of dug-out entrance.

i. *Preliminary work.*—When shell-holes are first occupied the men should be protected from air observation by screens of scrim canvas laid horizontally in the shell-hole slightly below ground level. The canvas should be treated with light distemper to tone with the surroundings.

It must be remembered, however, that a shadow will appear in all shell-holes except when the sun is actually overhead. In order to escape detection from hostile air observation, when a screen is used, it is important that the screen should be placed lower than the original ground level so that a shadow effect may be obtained.

Plate **187** shows a camouflaged shell-hole and also the shadow effect. The screen should be made of fabric attached to a frame of bamboo or flexible wood and allowed to sag in the centre. It should be placed at such a height as to conceal the regularity of the adaptation, and the garrison should remain beneath the screen when hostile aircraft are active.

For dry ground the screen should consist of scrim or canvas distempered or muddied to blend with the background. For wet ground, red American cloth makes an excellent photographic imitation of muddy water.

ii. *Disposal of spoil.*—All work should be done at night, the men remaining under cover by day. Spoil must on no account be thrown out on to the edges of occupied shell-holes. It should be emptied into adjacent unoccupied craters, care being taken not to fill them up. This would be disclosed on an air photograph.

iii. *Connecting up a line of shell-holes.*—Before making the connecting saps, hessian canvas or scrim, with the edges well serrated and slightly toned down with distemper, should be pegged with the edges taut over the intended excavation. Work must proceed underneath. The shell-hole area gives good background for the employment of canvas in this way, and no special care need be taken provided it is not raised above the ground level.

The surrounding shell-holes form a ready means for the disposal of spoil. Where the shell-holes are scattered and part of the background is still green, the overhead cover for the saps must conform with the tone of the background.

Fish netting having painted canvas strips to simulate grass, closely interwoven, should be used where grass exists.

iv. *Avoidance of tracks.*—Shell-holes must on no account be connected up by tracks. Visiting patrols should change their route every night. The garrison of occupied craters must not wander about in the vicinity of their dug-outs at night, and so augment tracks.

6. *Supply dumps.*—The successful camouflaging of a dump of this nature is of great difficulty. Supply dumps are usually located at the end of a light railway, or in the centre of a number of well-defined tracks, which multiply daily.

As the main work of distribution takes place at night, it follows that the ways of approach and departure must be well marked and easy to locate.

Accordingly an elaborate scheme of traffic following the lines of demarcation would in all probability break down under pressure and it would be of doubtful advantage owing to the loss of time entailed and the constant policing required. The best solution is to make use of a dummy dump. The railway and tracks should lead past the actual site and end at the dummy. The real dump should be sited on dark or broken background, use being made of any existing natural features such as bushes, or a ditch. These tend to break up any shadows created. Overhead camouflage should conceal the dump by day, the cover being made of fish netting interwoven with painted canvas strips.

Ammunition boxes and other light reflecting surfaces should be kept covered.

7. *Wire entanglements.*—Although judicious siting will often render wire invisible from the ground observer, the concealment of an entanglement from the airman calls for much ingenuity.

Wire under construction photographs light in tone owing to the trampling down of the ground by the wiring party. When the work is finished the tone becomes darker owing to the combined shadow cast by the entanglement itself and by the vegetation which may grow up in between the stakes.

This becomes very apparent in the case of wire before defence lines where the grass has been cut up to the entanglement.

If galvanised wire is used, the tone of the work will be lighter than when ordinary wire is employed. This soon grows rusty and consequently dark.

The following points, if observed, will tend to render any system of wiring less conspicuous :—

i. As thick belts of wire are impossible to conceal, entanglements should be thin irregular lines, spaced unevenly.
ii. Wire should be sited in long grass, or other high vegetation.
iii. Wooden stakes should be avoided ; they cast a far heavier shadow than iron supports.

6. *Application to miscellaneous organizations. Forward area.*

1. *Buried cables and air lines.*—The degree of concealment obtainable over lengths of buried cable varies directly according to the use made of natural advantages.

The siting of buried cables is therefore of great importance. The trace should follow any marked natural feature, or should choose a light background. When taking advantage of the line of a hedge the excavations should be on the shadow side and as close to the hedge as possible. Spoil should be kept under cover and not scattered about.

Buried cables are recognizable on an air photograph by reason of their blurred outline and by the straight line followed.

When poles for air lines are being erected in ground of a dark tone, the turf should be removed carefully and replaced when the excavations are filled in. Neglect of this precaution will result in the air lines being disclosed in the first photograph by a regular succession of white spots.

In snow the presence of the poles is similarly disclosed by a line of black spots caused by the thawing of the snow at the base of each pole.

Parties of men should on on account be told to follow the telegraph poles. This may be an excellent manner of directing them, but it will rapidly make a track.

In back areas, where air lines cross over fields which are being ploughed, the positions of the poles again become conspicuous by reason of the undisturbed earth immediately around the foot of the pole. This should be broken up by hand, to conform with the texture of the ploughed land.

2. *Machine-gun emplacements* :—

i. *Positions coming under air observation only, or possibly under the view of a very distant ground observer.*

Emplacements in areas comparatively immune from observed interruption can be camouflaged without much difficulty. Covers of the type shown on Plate 188 may be used.

They must be distempered carefully to match the background and must not be raised higher than necessary. The risk of shadow being great on a background of even tone, the fullest advantage must be taken of broken ground.

ii. *Positions in the forward area coming under direct view.*

These are obviously difficult to conceal. All preliminary work must be done at night, and concealment obtained by throwing the spoil in front.

Care must be taken to see that the general outline of the ground is not altered to a noticeable extent.

The camouflage cover is put in position before daybreak. This cover should not take the lines of a flat-top, but should resemble the false parapets made to mask the Oliver and Roland O.Ps. described in Sec. 5, 3, iii of this Appendix (*see* Plates 186 and 185).

In trenches, machine guns without head cover are easily located by the regular shape of the emplacement. Overhead cover should always be made use of; the fabric employed, be it natural or artificial, must conform with the characteristics of the surrounding parapet.

Gun positions to be used in emergency only must have gauze or scrim painted the local colour fixed in front of the embrasure, in addition to any overhead cover.

3. *Pill boxes and concrete structures* :—

i. *Sectional pill boxes.*—Pill boxes partially dug-in can be camouflaged in the same manner as machine guns.

The types of cover used will depend on the surroundings. In some cases it may be possible to prepare the cupola of the pill box in such a manner that it resembles the original background.

The front of the position must be carefully screened, and the loopholes concealed by gauze or scrim.

ii. *Concrete structures.*—These works, by reason of their elaborate nature and the quantity of material needed in their construction, will usually only be erected some distance behind the front line system.

In the choice of site, a background giving facilities for the concealment of tracks and spoil should be selected. Such locations may be found among old trenches or ruins.

These structures may be either partially dug-in or built up from the ground.

If local conditions necessitate the employment of overhead cover in the scheme for concealment it should be considered from the very commencement of the work (*see* Sec. 7, 5 of this Appendix). The structures may be disguised as non-important features.

Every effort must be made to break up the regular shadow of the structure, and where a cover is used, to see that its shadow blends with the general scheme.

4. *Mortar emplacements.*—The concealment of active mortar emplacements is a matter of great difficulty. These works are always situated in the front line system, and for this reason as well as on account of their destructive fire, are under constant and the closest scrutiny.

The emplacements should take the shape of shell-holes, or actual craters may be adapted for this purpose.

As a protection from air observation a circular screen fixed horizontally and made to fit the shape of the hole, about two or three feet from the surface, should be fixed in position. Rectangular shapes should be avoided unless they harmonise with the plan of the trench and ancillary workings.

The screen must in every case fit the outline of the emplacement. It must be distempered to match the colour of the soil, or, preferably, painted in oils if there is water in the vicinity. Before fire is opened the screen is removed, but an arrangement must be made for the rapid replacement of the cover on the advent of hostile aircraft.

5. *Observation posts* :—

i. *Ground.*—Observation posts in the vicinity of the front line have been dealt with under the heading of loopholes. (*See* Sec. 5, 3, of this Appendix.)

In rear of this area greater opportunities are presented for the selection of favourable positions. Ruins and other natural features can be adapted into observation posts without any great difficulty, but it is not wise always to select the most commanding view when there are other less conspicuous locations suitable for the purpose.

Regard must be had in the first instance to a suitable background, and the adaptation of the site with a minimum of labour. Any spot with a background such as a wall, a tree, or anything else that may prevent the head being silhouetted against the sky, will generally be found the easiest to convert.

It often occurs that sufficient command can be obtained in a building if the loophole is made near the ground. This will frequently solve the difficulty of background.

If, in the selection of the site, it has become necessary to make an artificial background out of painted canvas or any other likely material, it must be seen that it does not alter the original outline of the position to any appreciable extent.

In the making of actual loopholes, gauze, of a larger mesh than that used in the front line system, may be employed. Care must be taken to paint the gauze the colour of the surroundings and to simulate any distinctive design. This can usually be done in front of the site.

On no account should any unauthorized persons be permitted to approach the vicinity of the observation post. If such intruders are not dealt with at once, the disclosure and subsequent destruction of the work is only a question of time.

ii. *Tree.*—

(*a*) *Natural.*—A platform screened by the foliage of a tree will be efficient only for a time. When the leaves begin to fall, detection will be certain unless provision has been made for an artificial screen to be fixed amongst the branches immediately in front of the observer.

Such a screen must be designed to follow the lines of the branches and additional ones painted on the main part of the screen. These branches must be cut out in silhouette. No great ability is required to make an efficient mask on these lines.

The case of a defoliated tree is far more difficult. Advantage must be taken of the existing branches and a good background is imperative.

(*b*) *Artificial.*—Actual trees can be successfully substituted by artificial trees under cover of night. These dummies consist of a hollow trunk up which it is possible to climb, and so obtain a clear view through a prepared loophole towards the top.

As the manufacture of these trees takes time and requires skilled labour, a month must elapse between the choice of site and the night of erection.

The tree selected for reproduction must be not only suitable in girth, height, and form, but also must be in a position of fairly easy access; furthermore, it must be in an area where heavy and consistent shelling does not take place, so that it may stand a reasonable chance of life. (*See* Plate 189).

Dummy trees are also adapted for the insertion of periscopes, the observation being done in the security of a dug-out at the base. (*See* Plate 190).

7. *Application to artillery organizations.*

1. *Camouflage of battery positions.*—The presence of a battery is revealed invariably by the following indications :—

- i. Tracks.
- ii. Regularity.
- iii. Debris.
- iv. Shadows.
- v. Blast marks.
- vi. Flash.
- vii. Sound.

Plate 191 illustrates a badly sited and badly concealed battery position.

Points common to mobile and position warfare.

2. *Choice of position.*—If obtainable, an air photograph of the area should be used as a guide in the preliminary reconnaissance.

Careful selection of the ground with a view to concealment, and suggestions as to the manner in which concealment may be most expeditiously and simply carried out will render the task of the camoufleur far easier and more certain of success.

It is most inadvisable to select a position near any natural feature which may facilitate the enemy airman ranging a hostile battery in the event of discovery. The initial scheme must allow for treatment of dug-outs, and reserve ammunition as well as the provision of easily hidden approaches to the battery. It is not sufficient to hide the guns alone and neglect the remainder of the battery organization.

Camouflage is unlikely to serve its purpose if provided after the guns and personnel have been placed in position.

3. *Advantages of broken background.*—Considering Plate **192** it is easy to see how difficult the task of hiding a battery organization becomes when that battery is sited in open, unbroken country.

No natural features suggest positions for guns, dug-outs, or tracks; all have to be concealed, and at the same time no departure must be made from the natural tone.

Plate **193**, showing broken country, makes the advantages of that form of background apparent.

The many varieties of tone will tend to hide any alterations created by new work. By making use of shadows cast by natural features and of the features themselves, the artificial work necessary may be reduced to a minimum.

All work should be sited on the shadow side of natural objects.

It may be advisable to consider the question of siting from the psychological aspect. Woods, hedges, trees, &c., are all favourable to concealment, but at the same time are obvious positions for artillery.

It is clearly unsound to choose a hedge, when the enemy shows a particular partiality for engaging hedges. Hence, considering all things, it may be the most far-seeing policy to choose a less favourable position, rather than a naturally perfect but obvious location.

4. *Tracks.*—*See* Sec. 4 of this Appendix.

5. *Regularity of spacing.*—**In the study of nature from the air regularity is invariably a sign of man.** Regularity of spacing should be particularly avoided, and guns should be unevenly spaced as far apart as is compatible with control and the ground available. Such an arrangement not only makes it more difficult to locate them when silent, from the air, but to some extent minimizes the effect of hostile artillery fire.

6. *Debris.*—The presence of spoil is immediately detected by the airman, by reason of its light tone against the background. **A scheme for the disposal of spoil must be thought out before any work is commenced, and if overhead camouflage is to be erected this must be put up before a sod is turned.**

All turf should be carefully removed and stacked to be replaced on the debris when work is finished. It is usually impracticable to remove the spoil from the neighbourhood. Surplus excavation should be collected on the shadow side of any hedges, buildings, &c., and covered with material to blend the heap with the surroundings.

Debris should never be left uncovered, even under overhead camouflage, as the high light reflected from the spoil cannot be cut out by the fabric of the overhead cover.

7. *Shadows.*—Solid bodies are recognizable when photographed by their cast shadows alone.

The most dangerous time for the battery and the most favourable time for the airman is in the early morning or in the evening, when the sun is low and the shadows are long.

All excavations cast a distinct form of shadow, and can be identified accordingly without much difficulty.

The risk of detection is lessened by siting the work among broken ground, but whenever any emplacement or excavation is contemplated overhead camouflage should be erected first before any work is commenced. No cover is always better than a bad cover.

In striving to hide the small though well-defined shadow cast by a gun, the unskilled may easily produce a so-called cover which will cast not only a still more noticeable shadow, but have a completely different tone to its surroundings.

For mobile warfare, irregularly spaced guns, covered when not in action by painted scrim, garnished nets, or natural camouflage such as branches, will probably escape attention if well sited. Bivouacs may be similarly covered. Plate 194 illustrates a howitzer battery concealed by use of natural camouflage.

8. *The flat top cover.*—This form of cover consists of a foundation of either fish netting, or wire netting, having fabric of different natures sewn or tied to it.

Wire netting has the advantage of non-inflammability and is, therefore, preferable for covering guns, at any rate in position warfare. In mobile warfare, lightness and facility of handling being important considerations, the adoption of string netting in such circumstances is desirable.

The centre is opaque enough to hide the gun or emplacement underneath, while the fabric thins out towards the edge of the cover. This thinning out blurs the central shadows and at the same time is sufficiently irregular to prevent any defined outline.

There are no sides to the cover, and the intervals between the patches of material allow the light to penetrate and break any shadows caused by the cover itself. The cover is supported on a framework made of posts and wire, having the outside posts staggered. The height above ground varies according to the type of work beneath, but it should be as low as possible. The materials used on the cover vary according to the local conditions.

Owing to the time and labour required to erect this form of cover, it will only be practicable when a halt of some duration is anticipated.

The following schedule sets forth various types of cover to suit different kinds of country :—

Nature of ground.	Material on cover.
Grass country	Strips of green painted canvas knotted on foundation. Dense in the centre. Thinning out to edges.
Grass and earth mixed	Large irregular islands of scrim painted earth colour surrounded by canvas knots.
Shelled area	Large irregular islands of scrim (mud colour) in centre. Smaller patches at edges.
Mining districts	Black and white canvas strips alternating, with a preponderance of black.
Ruins	Red, white and brown strips mixed.
Gorse and heather	Coir nets placed on irregular framework.

NOTE.—In every case the foundation is the same, *i.e.*, fish or wire netting on pole and wire frame.

9. *Wire netting cover (see* Plate 195).

This cover is made up with a centre of ⅜-inch mesh netting surrounded by a fringe of ½-inch netting. A second layer of ⅜-inch netting is super-imposed immediately over the object to be concealed and the cover is then painted as explained below. The cover is designed mainly against photographic reconnaissance, and is semi-transparent when viewed optically at low altitudes.

It is essential that the object to be concealed should present a matt surface to the light, otherwise it will be distinguished through the cover, the extent of which is determined by the length of the cast shadow. This type if properly handled should throw a shadow of negligible quantity, but if the netting be allowed to sag and thus present an opaque surface to the sun's rays this advantage will immediately be nullified.

Up to the present, trials have only taken place over grass and chalk country, and it is therefore impossible to lay down any definite colouring for other forms of background. A very dark non-reflecting background such as a spoil bank in a coal mining district would be most unsuitable for the employment of this cover, which depends upon reflected light for its opacity.

The degree of efficiency of the cover may be said to depend on the reflective properties of the wire mesh. Actually an all white cover is more opaque than a green. Continuing down the scale we arrive at the black painted netting which is valueless, being transparent.

Although the transparency of the cover when viewed from beneath gives little sense of security it must be remembered that this type of screen does not depend upon mass, but on an infinite number of minute curved surfaces reflecting light in every direction. It is an elaboration of the old-fashioned bead blind, where those inside had an undisturbed view from the windows thus equipped, knowing that they were invisible to the passer-by in the street.

Advantages.—The chief advantages of the wire net cover over the old flat top are—

i. Its reliability against air stereoscopic photography, up to the present. The old flat top could almost invariably be detected by this means.
ii. Its non-inflammability.
iii. Its durability.
iv. Its comparative ease in manufacture.
v. The smaller area necessary.

Disadvantages.—The chief drawbacks are the present lack of an easily portable form of wire net cover and the difficulty in handling large areas of netting.

SCHEDULE ILLUSTRATING TYPES OF WIRE COVER USED ON VARIOUS BACKGROUNDS.

Nature of ground.	Treatment of cover.
Grass land	Cover painted mid-green with a tendency to lighten tone in centre. Edge disrupted by black paint.
Chalk patches and grass land intermingled.	Mid-green and white patches; disrupted edge. White patches should be over object beneath cover.
All chalk background, or white metalled road—or concrete.	All white cover.
Sand	Yellow-brown to suit predominant natural tone. No confirmation yet obtained by experiment.

10. *Blast marks.*—After firing a number of rounds in the same position blast marks will appear in front of each gun. These are in the shape of white fan-like patches and are quite unmistakable.

Their presence may be avoided if the situation will allow the battery being sited so as to fire over :—

i. Water.
ii. A metalled road.
iii. Shell holes.
iv. Rock or limestone.

11. *Blast marks can be hidden by :*—

i. Pegging down $\frac{1}{4}$-inch mesh expanded metal in an irregular-shaped patch in front of each gun. One thickness resembles thin grass. Two thicknesses resemble medium grass. Three thicknesses resemble long grass.
ii. By unrolling an irregular net of wire or string garnished with canvas knots or patches over the blast mark when the gun has ceased firing. This net must be removed before the gun re-opens fire.

12. *Blast marks in snow.*—These appear black fan-shaped patches, and the only sound method of concealment is to cover them with irregular-shaped sheets of white calico. They may also be concealed by snow itself or by crushed chalk if available.

13. *Flash.*—No method has yet been devised of hiding flash from the airman.

Screens of brushwood or garnished wire netting may be erected to hide the flash from balloon or ground observers. These screens may, however, prove a great source of danger, as owing to their peculiar shadow they are easily recognized by the airman and on the air photograph, and their presence may lead to suspicion.

14. *Ammunition.*—Provision for a certain number of complete rounds will be made in the gun emplacement. Any reserve dump of ammunition in the battery position should be sited with great care.

Shell and cartridges should be stacked on the shadow side of hedges, ditches or buildings, and covered with camouflage.

In open country the rounds should be stacked in small irregular heaps unevenly spaced.

As a large amount of traffic must necessarily take place about these dumps, the provision of suitable tracks must be foreseen before the dump is sited.

15. *Personnel and dug-outs.*—**No unnecessary excess of personnel should be accommodated in the gun position proper.**

Apart from considerations of health and casualties the presence of a large number of men in the battery position adds largely to the difficulties of the camoufleur. Extra dug-outs have to be made, and extra tracks foreseen.

It is also extremely difficult to keep unemployed men under cover when the situation is quiet and all appears safe.

Surplus personnel required at the battery should be accommodated well to a flank. Their dug-outs, if provided, should run if possible at right angles to the battery position, thus avoiding any possible suspicion of another battery position.

During their construction care must be taken to guard against the same causes which tend to give away a battery position when the gun emplacements are being constructed.

16. *Wagon and horse lines.*—*See* Sec. 10, 8 of this Appendix.

17. *Dummy positions.*—These have a dual purpose :—

i. To attract the attention of the airman and thus cause him to overlook an occupied and active battery position. (*See* Plate 196.)

ii. To simulate a large concentration of artillery by augmenting the batteries already on the spot.

Dummies are invaluable in areas where the absence of suitable natural features renders successful camouflage extremely difficult.

For instance, a battery is obliged to take up a position as shown on Plate 196. The provision of a suitable covered approach is an impossibility, and the only successful solution is a well-defined track passing through the battery to a dummy position at a good distance away.

Hence, given space and time, a dummy position cleverly sited and exploited is an invaluable addition to the concealment scheme. The moral effect of a successful dummy is excellent.

A dummy position must always be placed at a safe distance from the parent battery, and the constructors must avoid placing it near any other important point.

18. In the construction of a dummy the following points should be noted :—

i. The dummy must be realistic. Obvious work should be avoided as tending to disclose the real object of the position.

ii. Tracks must be made and maintained. It is not sufficient to make a path and then leave it. A few days' neglect will be noticed on a photograph. Men must be detailed to walk about the dummy position in the day, and at night a wagon should drive up and down the track.

Rain also tends to eliminate tracks.

iii. Provision must be made to simulate spoil. Turf must be removed and surface spoil scattered about. Old ammunition boxes, sandbags and other debris can also be distributed.

iv. Dummy blast marks should gradually be made.

It is unnatural for well-defined traces to appear suddenly. These can be simulated by cutting the grass or removing vegetation from the front of the supposed gun or by laying down painted scrim.

v. Flash screens may be erected, if time permits, in suitable positions calculated to attract attention.

vi. Arrangements must be made for firing either an actual gun or flash puffs frequently from the dummy position, preferably when hostile aircraft are about.

A gun or bombs should also be fired from the position on days favourable for sound ranging in order to deceive this form of enemy intelligence, but the deception caused by such positions will be short lived unless live rounds are fired from them now and then.

Points special to mobile warfare.

19. *Direct observation.*—In the event of a battery coming into action in an open position speed is obviously the first essential, and there will usually be little or no time for any artificial camouflage. At the same time, every effort must be made to conceal the guns until the last moment so that their fire may come as a surprise.

It is fatal to take up a position on the sky line. In this connection the probable position of the hostile observer must be considered, as well as when deciding on the line of approach.

It is unsound to come into action if it can be avoided near any prominent natural feature, such as the end of a wood, a large solitary tree or clump of trees. These objects would facilitate the rapid ranging of the hostile artillery on the battery when it had been located.

20. *Choice of background.*—Ground observation is of primary importance, although precautions against the airman must on no account be neglected.

The background selected should be broken and full of shadow. Guns should come into action if possible in shadow, and as much use as possible must be made of natural irregularities such as bushes, holes and ditches to conceal wagons and personnel.

21. *Painting of guns and vehicles.*—In the past guns and vehicles were painted in a standard pattern for universal use. This pattern was a combination of various colours, and it was thought that the effect would tend to break the hard outline of the treated object and make it blend with any form of background.

However, experience shows this supposition to be erroneous, and that it is impossible to standardize with any success. On Plates 197 and 198 are drawn forms of patterns suitable for different types of background.

It is obviously impossible to attempt to repaint all battery vehicles to suit each succeeding type of country. The most effective method is a two colour scheme, making use of counter shading, *i.e.*, painting the parts in shadow, light, and the rest of the object, dark.

It is dangerous to put too much trust in paint alone. A successful combination in the morning may become hopeless later on in the day when the light has changed. Paint alone will never defeat the tell-tale shadow.

22. *Gun teams and wagons.*—Besides the actual guns and their personnel the teams and battery wagons must be considered. All transport must take up a position hidden from the ground observer, and on the shadow side of natural features, of a sufficient height to cast a long enough shadow.

Men should on no account look up at aircraft, and they must keep still and not walk about.

Points special to position warfare.

23. *General.*—Although in this case time is usually on the side of the camoufleur it must not be forgotten that the enemy will be able to draw on far more detailed and accurate observation.

He will be able to co-ordinate results from the reports of the following:—

i. Optical observers.
ii. Air photographs.
iii. Sound rangers.
iv. Flash spotters.
v. Agents.

It is essential that, if practicable, a good and recent air photograph should be available before the choice of location for the battery position is made in order that the greatest advantage may be taken of natural surroundings.

Especial care and foresight must be used when any large concentration of artillery takes place. The traffic problem and ammunition supply will require much preliminary work. (*See* Sec. 10, 2 of this Appendix.)

Camouflage factories must be warned well in advance in order that no shortage of artificial fabrics may ensue.

24. *Decauville railways.*—In many cases, owing to the number and weight of shell handled, a Decauville track will be run into the battery position.

Complete camouflage is rarely possible. Garnished nets or painted scrim lengths laid over the track when not in use may be successful. This form of concealment requires constant attention and, for any length of track, vast quantities of material. The most economical and successful method is to prolong the track to a dummy battery or dump. If necessary this dummy track can be made to run over the top of the overhead cover.

A Decauville railway track can be simulated by painted canvas or rope.

25. *Railway mountings.*—Owing to the size and accompanying railway track the camouflage of this form of weapon is of extreme difficulty and requires much skill and ingenuity. Fortunately notice is usually given before this type of gun is brought into action, and it is thus possible to prepare the elaborate camouflage necessary.

The nature of this equipment necessitates laying a spur from the local line to suit the requirements of the gun. As in the case of the Decauville the concealment of the entire spur, unless the natural surroundings are exceptionally favourable, is an impossible task.

The track should be continued past the actual emplacement to a dummy gun or buffer stop. It is also advisable to prepare several alternative positions and dummies, which all tend to confuse the airman.

It will not be practicable to erect overhead cover over the gun owing to the great size of the structure required.

The gun must be transformed into some non-important object.

Examples :—

- i. *A Shed.*—Care must be taken that the construction is strong enough to resist the shock of discharge.
- ii. *A Dump.*—In the Great War a 12-inch howitzer played the part of a small dump with great success.
- iii. *Brushwood and fallen tree debris.*—The mounting should be covered with a garnished net or painted scrim sheet and branches leant against it.
- iv. *Natural features.*—Every advantage should be taken of natural features such as a tunnel or railway yard. The gun could be kept in the tunnel when not in action, or in one of the many sheds found in a yard.

26. *Super-heavy road mountings.*—By reason of the great weight of this equipment and the difficulties of ammunition supply the position occupied should always be near a good road, which places certain limitations on the choice of ground.

The judicious study and use of natural features is more than ever required to attain a successful end to the concealment scheme.

Size will usually prevent the use of complete overhead cover, and it is better to utilise natural irregularities and to mask the dug-outs and approaches than to attempt any elaborate work on the guns themselves. When the guns are considered, care must be taken to break up the regular outline of the earth box.

In open country large ordnance are best spaced irregularly and covered with fabric, either garnished nets or scrim. This helps to distort the shadow and hides the shape.

In wooded and broken country positions can readily be found. Guns can be placed under trees and nets spread over them, using the trees as supports. Trees can be augmented by dummies made of wood and painted canvas strips. Buildings and ruins also lend themselves to the easy concealment of guns.

8. *Application to ruses.*

1. *Snipers' heads.*—The special use of snipers' heads is the locating of enemy snipers. They are modelled in papier mache.

In use the head is raised above the parapet of the trench to a height generally decided upon in advance by means of a device which admits the use of a special periscope later on. Should the enemy sniper take advantage of such an excellent target a clean bullet hole through the dummy head would be the result. By making use of the special periscope and the appliance mentioned (*see* Plate 199) the hiding place of the sniper can be located.

2. *Chinese attacks.*—These consist of dummy silhouette figures which can be manipulated to simulate an actual attack in position warfare under favourable conditions. Plate 200 explains the method of employment of the silhouette figures.

The device has been employed with considerable success and would serve to disguise the locality of the actual attack or possibly make the enemy disclose himself.

When these figures are used in conjunction with smoke screens or in misty weather it is impossible to distinguish them from real men advancing to the assault.

The production calls for a good deal of skill and knowledge of drawing and colour. In their present form they are intended to defeat ground observation only. They are without any photographic value ; the successful application of the idea to areas both anti-optic and anti-camera is a matter for investigation.

Photographic evidence of the move of troops is concerned more directly with the effects of such evolutions on the normal landscape and not with the actual cause.

3. *Dummy concentrations.*—The camera never gives a false representation. This is a true statement and recognized fact, and therefore the fullest use should be made of it in all schemes of deception. Hence the dummy concentration, whereby the reproduction in simple form of war materials at certain points leads the enemy into the belief that an attack is impending.

To be successful, such a concentration must be on a large scale, which necessitates the construction of these forms in such a manner that large quantities may be packed into a small compass for easy transportation.

There is no necessity for the painting of these appliances to be too realistic as they cannot be judged at close quarters by the enemy airman. The first essential is for the forms to cast shadows which cannot be distinguished from the shadows of the real objects in photographs taken at a height of 5,000 feet. At a lower altitude than this it is unusual for an airman to fly over enemy country.

Experiments are in progress on these lines, and Plate **201** shows the drawing of a G.S. wagon in silhouette form together with the aerial proof of its effectiveness at 1,000 feet.

The possibilities of this method of deception are great, since the silhouettes could be manufactured in large quantities quickly and cheaply, in addition to which very little transport would be required to carry out an effective scheme (*See* also Plates **202** to **205**).

The appearance in air photographs of what appears to be war material and the continual changing of its disposition is bound to have a puzzling effect on the mind of the enemy reader.

Even should the ruse be discovered eventually owing to bad management in the matter of camouflage and tracks, it is more than likely that in the interim much good has been done by diverting attention from the real concentration. There are times when some attempt must be made to camouflage these duplicates. In all warfare important objects will be hidden as much as possible, and therefore in all simulations similar objects should be correspondingly dealt with.

A dummy gun, for instance, should have a camouflage pattern painted on it, and, when stationary, provision made for overhead cover.

The provision of adequate tracks is of first importance. These are made more easily by the actual vehicles themselves. The various devices for simulating tracks are far from being perfect.

It would not do for a double track to appear when a vehicle has only done one journey. The best solution is for the real vehicles employed to make tracks in all directions over the ground and so create a maze from which it would be quite impossible to detect actual individual tracks.

The unloading of these dummies prior to erection must also be considered. This should be done on a roadway and not in the centre of the supposed activity, where tracks would converge and make a veritable bulls-eye.

9. *Application to tanks.*

1. *Vertical concealment.*—Tanks can be hidden from the air by covering them with the ordinary flat-tops in the usual way and, in northern latitudes, choosing positions where there will be shadows such as under, or on the north side of, trees.

If it is possible for a tank to be placed in constant shadow, the flat-top may be dispensed with and any dark, rough fabric thrown on to the tank to hide any reflection of top light such as from the tracks. It must be remembered that any object with a large area of polished surface cannot be hidden unless some light absorbing medium is placed over those parts.

If possible, sites for tank parks should be chosen immediately adjacent to roads and against buildings, trees or any objects that will cast big shadows. It must not be forgotten, however, that a white-washed building will reflect a certain amount of light on to a tank, so if there are other more suitable buildings in the vicinity they should be chosen in preference.

If such positions are not possible, a pergola of suitable camouflage material should be erected immediately adjoining the roadway, running alongside a hedge, ditch, or some feature that will help to merge any shadow thrown by the pergola. Failing all these, precautions must be taken to create tracks running beyond the park to a distant dummy, the park itself being camouflaged.

The elaborate preparations for an offensive will, usually, extend into many days, during which time photographic and other evidence is accumulating. Every endeavour must therefore be made to ensure the suppression of tracks vital to the success of the future operations, and photographic evidence supplied to lead the enemy to a false deduction as to the direction of the impending offensive.

As the whole question of the concealment of tank tracks bristles with difficulties, it is chiefly by exercising ingenuity in the matter of false tracks and the use of dummies that the enemy will be deceived.

2. *Horizontal concealment.*—Something can be done to break up the outline of a tank by the method known as disruptive painting. (*See* Sec. 3, 6 of this Appendix).

As this is only of use when the tank is at rest and the background unchanged its employment in actual warfare is of limited advantage.

Experiments are in progress to ascertain whether it is possible by a system of painting to appear to change the direction of a moving tank to confuse the gunner when ranging. If successful, it may result in a wider application of the principle.

The use of stereotyped designs on particualr objects cannot be condemned too strongly. If persisted in, "camouflaged" material would become known by these patterns.

10. *Application to rear organizations under vertical observation only.*

1. *Defensive positions.*—As with trenches, defensive positions cannot be concealed effectively. Camouflage should be confined to trenches forming part of a system of defended localities.

The wiring up of the positions should not be done in thick belts, which can easily be identified in a photograph. A systematic spreading of the wire over a larger area will lower its tone considerably. In fact if the work is well done it will not be visible. To achieve this end the use of wooden stakes should be avoided if possible.

An opportunity occurs here of making use of dummy trenches and wire in front of certain points to draw attention from camouflaged positions. These false works must not be near the actual trenches.

In clay soil sufficient earth should be excavated to cover any grass or undergrowth in front of and behind the trench. This will give the effect of a fully excavated trench in a photograph with the addition of certain devices mentioned in Sec. 5, 1, ii. of this Appendix to represent depth.

Where the sub-soil is chalk, the turf should be preserved and laid, grass side down, in the excavation. This will give a lighter shadow than the methods of Sec. 5, and although not perfect when photographed at a low altitude, will tone fairly well with the shadow contained in a fully excavated chalk trench if photographed from 5,000 feet or above.

The amount of light reflected from the sides of a chalk trench is responsible for the reduction in tone of the shadow.

Suitable ditches can be converted quickly to give the effect of actual trenches by removing the turf in front over an area to correspond to a normal parapet, and placing the cut turves grass downwards in the rear of the ditch to represent the parados.

2. *Dumps.*—The most usual photographic sign of a dump is an irregularly worn patch of earth towards which many tracks converge. The importance usually varies according to the size and number of tracks.

In back areas dumps are usually found in the midst of multiplications of railways and roads; in fact, anywhere where the transport problem is made easy.

Lax track discipline has been responsible for more damage to dumps than any other cause. This is less excusable when in the case of the majority of dumps excellent roads and paths are already in existence.

Judicious use of these existing roads and strict traffic discipline, combined with a careful choice of background in the siting of the actual dumps, will reduce the chance of detection greatly, although the successful camouflage of a large depot is generally a matter of great difficulty.

An intelligent use of the knowledge of tone values will enable sites to be selected affording favourable backgrounds of a lighter tone, often adjacent to main roads, rectangular in shape, and in appearance the very antithesis of a dump.

Failing such a site, any field of a similar shape could be chosen and stripped of any turf or undergrowth at the edges, the ordinary traffic of wagons and men being responsible for the obliteration of the remaining grass in the centre. A dump arranged in this manner stands quite a good chance of escaping observation for a time.

Entrances and exits to these dumps must be fenced strongly to make the traffic keep within limits and not cut off corners.

At the present stage of camouflage it is not practicable to erect an overhead cover over an entire dump with the exception of certain isolated cases. A forest of supports would be required to support the fabric, and these posts would get in the way of traffic and be a great obstacle to the efficient working of the dump. The fabric itself would require constant attention, while the repeated sagging of the material would make it extremely difficult for the tone and appearance of the original background to be maintained.

3. *Headquarters.*—The presence of troops and consequent activity in the vicinity of headquarters often enables the enemy airman to locate their situation without reference to a photograph.

All things being equal a site away from the main road is the first essential, and strict track discipline must be enforced to prevent the numbers of tracks which will otherwise grow up.

The necessity of speedy communication, however, often demands that these places shall be sited on main roads. Against such backgrounds ordinary activity can be seen by the airman.

A situation demanding the speedy despatch of troops by daylight gives the enemy a great advantage in locating the hub of the activity, and the remedy lies in the selection of a day rendezvous for despatch riders and messengers at a suitable point some distance away from the actual headquarters.

Prominent natural features should be avoided, as they afford excellent points of reference for the enemy, and may be used to calibrate guns on even if there is no visible or known target.

All windows must be screened at night with opaque material, especial care being taken with skylights. All lights carried by vehicles which may call at headquarters must be extinguished some distance away and on no account lighted on departure until they are out of the prescribed area.

4. *Camps.*—Wooded country is the best situation for camps, which should be sited under trees and immediately adjoining roads and paths.

Regularity should in all things be avoided, and no attempt made to lay out the camp on straight lines.

5. *Tents.*—Should be painted a burnt umber for all positions. If there are no trees on the site chosen, broken ground or ground covered with gorse or bushes will be found useful to assist concealment. These will help to merge the shadows of the tents. Tents should never be in line if they are to escape observation.

The tops of the tent poles should be connected if possible with rope or wire and branches of trees or bushes tied on to these connections; this will help to distort shadows and to conceal tracks around tents.

6. *Hutments.*—Trees casting shadows on huts assist any camouflage scheme. The roofs should be textured with a broad design, black and green if there is no light background, the black preponderating at the edges to merge the design into the shadow.

When siting huts, the orientation must be considered if they are to be camouflaged.

On very low structures painted scrim has been used effectively to eliminate shadows. The slopes of the roofs are continued on the shadow side down to the ground, and holes are cut into the scrim to give the effect of shadows of small objects to assist in the deception.

7. *Billets.*—The first consideration is the suppression of tracks. If the billets are not on a roadway extra precautions must be taken to use only the existing paths. For further information on this point *see* Sec. 4 of this Appendix.

If there is a choice of billets those adjoining marked ground features should be selected provided there is easy access to the road.

Sky lights and windows should be covered with opaque material at night.

Men must on no account loiter about outside billets. Men being drilled on roadways must break up when hostile aircraft approach and seek the cover of the hedges or stand still on the sides of the road.

In fields, formations must be broken up immediately, and the cover of trees or hedges made use of if available. The exercising of troops in fields should be arranged so that the wear is even over the whole area.

8. *Horse lines, wagon and lorry parks.*—It is not at present practicable to erect overhead camouflage over such large areas as would be effected in this connection, for the reasons given under para. 2 above.

Judicious siting, having regard to suitable roads, will certainly lessen the chance of detection, but unless exceptional natural advantages are available the task is one of extreme difficulty.

Wagons and lorries should be parked on the shadow side of trees or buildings. A road must be adjacent or the position will be given away at once by tracks.

The track problem of any horse lines needs the greatest foresight. Wired-in routes should be provided for traffic and easy facilities provided for watering. Moreover the lines themselves have to be provided with a solid standing.

It is possible to conceal horses in woods or ruins and arrange for the tracks to and from the water troughs to run past the actual lines to a dummy prepared at a distance.

It is an impossibility to conceal horse lines sited in open country.

9. *Aerodromes.*—It is impossible to conceal these for any length of time, owing to their size and constant traffic.

Aerodromes sited by a wood may be concealed by continuing the pattern of the trees on to the tops of the hangars.

These should be placed in clearings in the wood so that the edge of the building will be in prolongation with the edge of the woods.

The non-shadow side of the wood should be selected; this does away with the danger of a tell-tale shadow caused by the different height of the hangar and the trees which would occur if the building was on the shadow side.

A certain aerodrome in Belgium, during the Great War, escaped observation for a long time. This place was built on a market garden and the rectangular patches of the crops were reproduced on the tops of the hangars. The background being dark, the shadows did not show in the air photographs which were taken. Eventually a photograph taken when the shadows were very long disclosed the actual situation. This shows how much can be done when an intelligent choice of site is made.

11. *Application to permanent fortifications and large buildings.*

1. *Permanent fortifications.*—The size and regularity of design of these works renders their successful camouflage by day practically impossible.

The parade grounds of forts must be raked over, tarred, and scattered with ashes or coke breeze.

Bushes and vegetation should be encouraged to grow over the works and sentries should only use as a regular beat some hard surface which will not show any traces of their track.

The guns themselves and the well of the emplacements must be covered by overhead camouflage of a design to blend with the local background.

The successful treatment of the concrete aprons is of some difficulty. Although turf can grow if the sods are cut sufficiently thick, the blast of the guns will soon remove the grass. Expanded metal bolted into the concrete is possibly as good as anything; this must be continued on to the grass on the edge of the apron and should be well serrated. (*See* Sec. 7, 9 and 10 of this Appendix.)

Use may be made of a dummy battery position in the vicinity, to which the road leading to the real fort can be made to appear to lead.

When viewed from the sea, guns and certain buildings belonging to forts, such as battery commanders' posts or position finding cells, may occasionally be silhouetted against the sky. A scheme must be evolved to create a background for these prominent objects. Painted canvas screens may be thus utilised, but it must be remembered that usually these erections will be in a very exposed position and therefore must be of an exceptionally strong design.

2. *Large buildings.*—Size and regularity are again against the camoufleur and concealment by day is an impossibility. The utmost that can be done is to

treat the roofs and sides with a preparation of matt paint and make a design to conform to the general lay-out of the surrounding features.

In all camouflage work it may be taken as a general rule that, when treating an object with paint with the idea of defeating the airman, its form must be broken up by others of a totally different character. For instance, objects having rounded formations should be painted with rectangular or other shapes contradicting their features.

There are exceptions to this rule, and one is the method of painting to be applied to a very large building which obviously cannot be camouflaged effectively against the eye or the camera owing to its great shadow. The only thing to do in this case is to repeat the rectangular design of the building on a much smaller scale and endeavour to make the structure look like a number of smaller houses. It must be remembered that roof area conveys the idea of size to the airman. A tall building amongst others is not nearly so noticeable as a single-storied one covering a large area.

To break up the building successfully it will be necessary to divide the roof into rectangular shapes with ample spacing between, painted a matt black to convey the idea of shadows. The design must be continued down the sides of the building. An illustration of this method of painting is shown on Plate 180.

The paint used should be of the mastic variety to enable the employment of coke-breeze. This combination makes a lasting surface which will photograph a dark tone. It must not be thought that this treatment is meant to defeat the camera under all conditions. It may possibly deceive the photograph reader for a time when the building so treated is amongst others. The painting is intended to deceive the bomber.

The camouflage scheme should always include provision for a dummy to mislead the night bomber. An area some distance away should be illuminated in such a manner that regular spacings of any skylights are reproduced on the ground. Very simple measures only need be taken to be effective.

The lights are placed on the ground, and diffusive material such as muslin or scrim, fixed horizontally on a framework, a safe distance above. Opaque side screens will prevent oblique view of the lights.

APPENDIX XI.

Sangars.

1. Sangars are breastworks made of stones and are used to provide cover against rifle fire in rocky country where the construction of trenches is impossible (*see* Plates **206** and **207**).

2. Design of sangars :—

i. A square gives four bad salients. A circle gives diminished fire power, but experience has shown that a circular trace is normally best for small works and is the easiest to construct.

When the sangar is overlooked from within range of rifle fire an inner ring of stone wall is necessary to form a parados. The trace of the walls is therefore two concentric circles, the distance between the walls being about 3 feet.

ii. Thickness of walls.—3 feet at the bottom and 2 feet 6 inches at the top.

iii. Height of walls.—4 feet 6 inches.

Details of a section of a stone and earth sangar to resist shell fire are given on Plate **206**.

3. The size of a sangar necessary to accommodate a certain garrison can be calculated as follows :—

On the assumption that the diameter of a circle is, for all practical purposes, one-third of the circumference.

The number of the garrison gives the diameter in feet of the sangar measured to the inner edge of the outer wall. This allows one man for each yard on the perimeter.

4. *Miscellaneous points on sangar building* :—

i. Complicated doors should be avoided ; at first instance a space 3 feet wide should be left in the wall to serve as an entrance. Stones should be collected and placed inside the sangar on either side of the gap in order that the gap may be built up when the garrison is inside. Later a more convenient entrance protected by a traverse can be made.

ii. A course of turf or sandbags filled with sand or earth, where procurable, should be laid on the top of the parapet and parados to minimise the effect of splinters.

iii. The top of the walls must be made as irregular as possible in order to conceal the heads of men looking over. Stones, rather larger in size than a man's head, provide the best head cover.

iv. The largest stones possible should be used in building and a supply of stones for repairs collected inside the sangar.

v. Loopholes are difficult to construct without the use of timber, wooden box loopholes or steel plates. Where none of these are available and the provision of loopholes is considered to be essential, large stones should be used, care being taken that the opening on the outside of the wall is as small as possible. Under normal conditions loopholes should be about 1 foot 6 inches above ground level and 3 feet apart. When loopholes, are provided, the trace of the parados wall must be adjusted to permit a man to fire lying down.

vi. Builders should work in pairs, one man inside and one man outside the wall. Carriers to be divided into groups of 6, one group of carriers working with each pair of builders.

5. *Calculations for time and labour in construction.*—A rough idea of the time and labour required to build a sangar can be formed from the following data which are based on experience with well-trained men.

When materials are available within 50 yards of the site of the sangar 6 builders and 18 carriers with 6 picks and 6 shovels can construct a sangar for 20 men in $2\frac{1}{2}$ hours.

6. *Wire obstacle.*—When the stores are available a wire obstacle should be constructed to provide additional security for the garrison.

Two rings of double apron fence, sited about 15 and 30 yards from the sangar, should be erected when time and materials admit.

INDEX.

NOTE.—The Plates will be found following this index.

A.

C.

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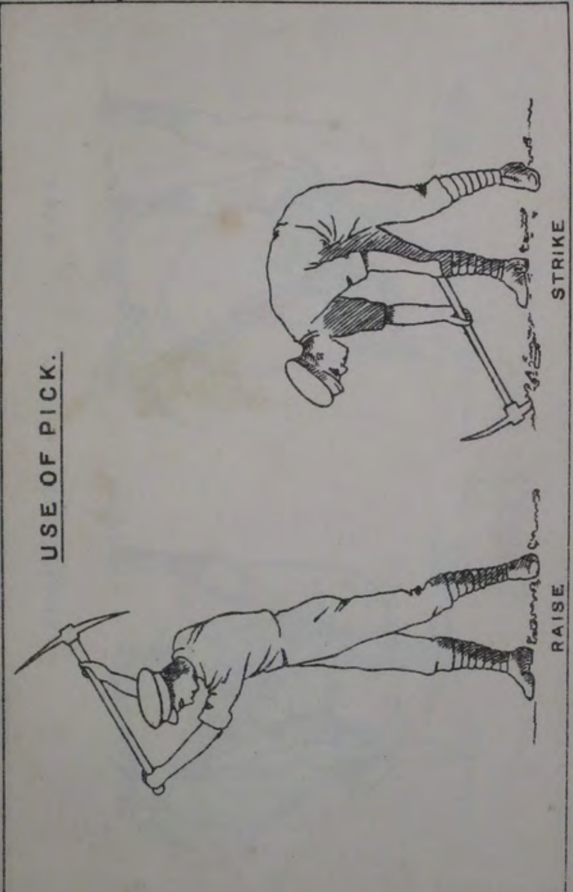
R

Z.

Printed under the authority of His Majesty's Stationery Office
By Harrison and Sons, Ltd., 44-47, St. Martin's Lane, W.C.2.

(B 28/27)Q 2158—147 500 12/25 H & S, Ltd. Gp. 28. 26/Ptg/486



Malby & Sons, Lith.

USE OF PICK.

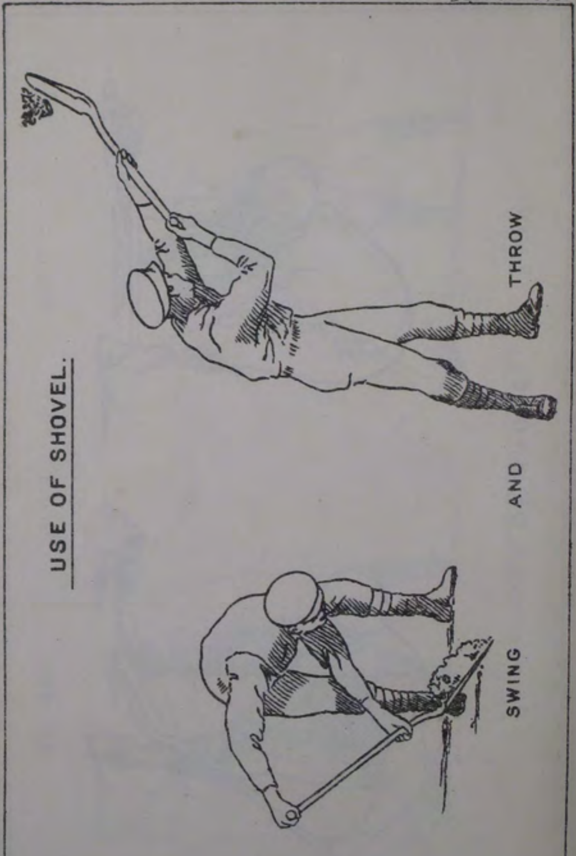
1703.

Malby & Sons Lith.

USE OF SHOVEL.

SWING AND FILL

Malby & Sons, Lith.



USE OF SHOVEL.

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FASCINES.

WITHES.

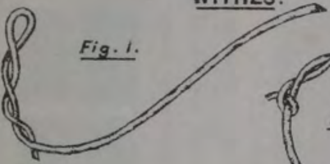


Fig. 1.

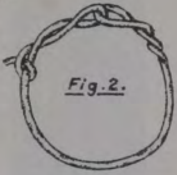
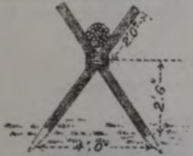


Fig. 2.

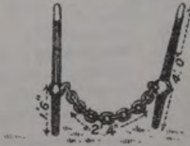
Fig. 3.

FASCINE TRESTLE.



Stakes about 6½ feet long

Fig. 4.



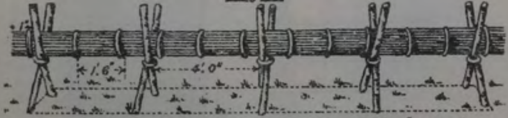
FASCINE CHOKER

For compressing brushwood

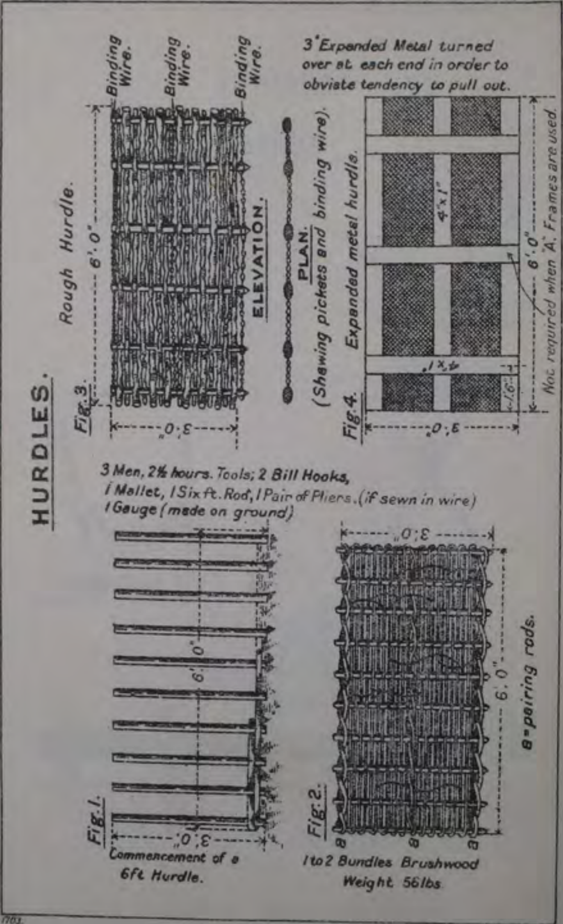
18-FT. FASCINE

Trestles 4' apart

Fig. 5.



Suitable tracing rectangle measures 16'.0" × 4'.0"



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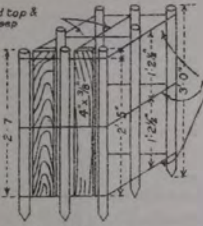
COLLAPSIBLE WIRE NETTING GABION.

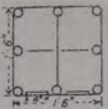
Wire Netting Omitted.

FIG. 1.

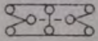


ISOMETRIC VIEW

FIG. 2.



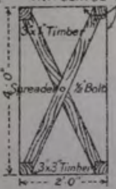
PLAN (open)



PLAN (closed)

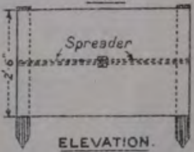
LIGHT COLLAPSIBLE GABION OF CANVAS

FIG. 3.



PLAN.

FIG. 4.



ELEVATION.

EXPANDED METAL GABION.

FIG. 6.

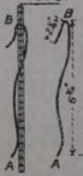
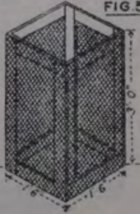


FIG. 5.



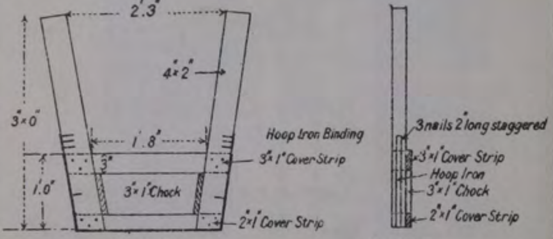
VERTICAL SECTION.

1. *The fastener prevents the raw edges of the X.P.M. bulging outwards*
2. *The end A is inserted just far enough to pass through the overlapped sheets and the fastener is then pressed vertically downwards by tapping it with a hammer. This causes the hook end B to engage also through the overlapped sheets. The hook is driven down as far as it will go. It is impossible to withdraw without tools.*

N.B. Wooden framework is not essential for making the gabion and is removed when the gabion is ready for use.

SMALL "A" FRAME.

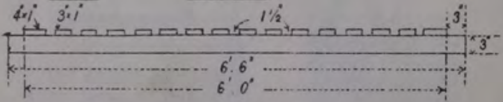
FIG. 1.



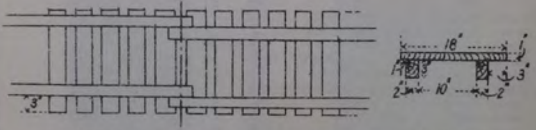
ELEVATION   SECTION

TRENCH BOARD

FIG. 2.   ELEVATION



PLAN



NOTE *One of the best methods for preventing Trench Boards from becoming dangerously slippery when muddy and wet, is for each slat or tread to have a straight piece of No. 5 B.W.G. wire fastened along the top of its centre by not less than 5 Staples.*

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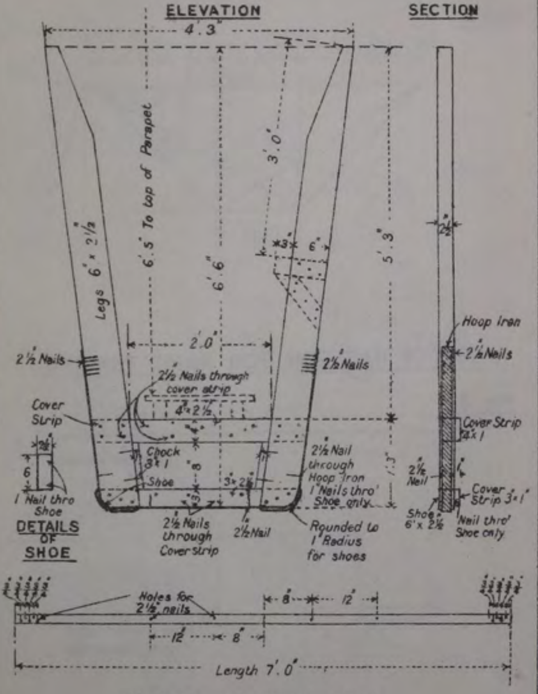
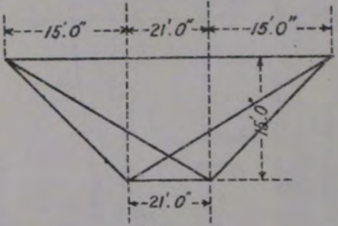
DEEP "A" FRAME



DETAILS OF HOOP IRON.

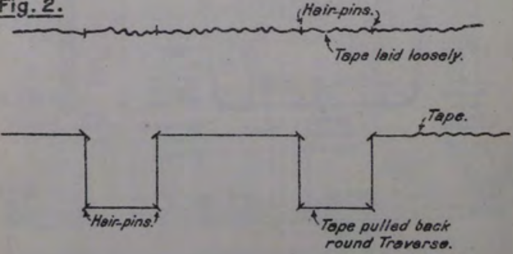
TAPE TEMPLET.

Fig. 1.

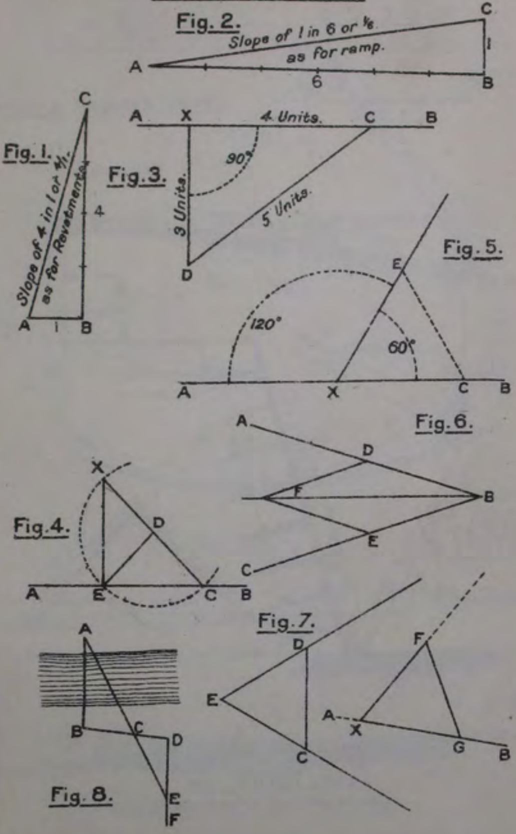


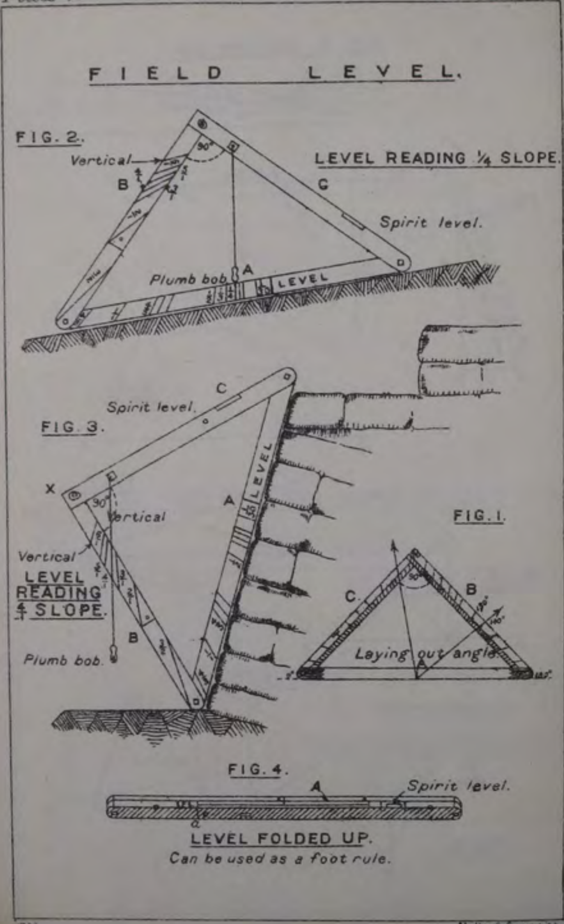
USE OF HAIR-PINS FOR RAPID TRACING.

Fig. 2.



FIELD GEOMETRY.





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IMPROVISED LEVEL

Fig. 1.

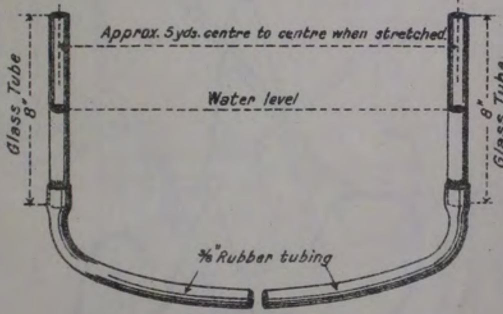
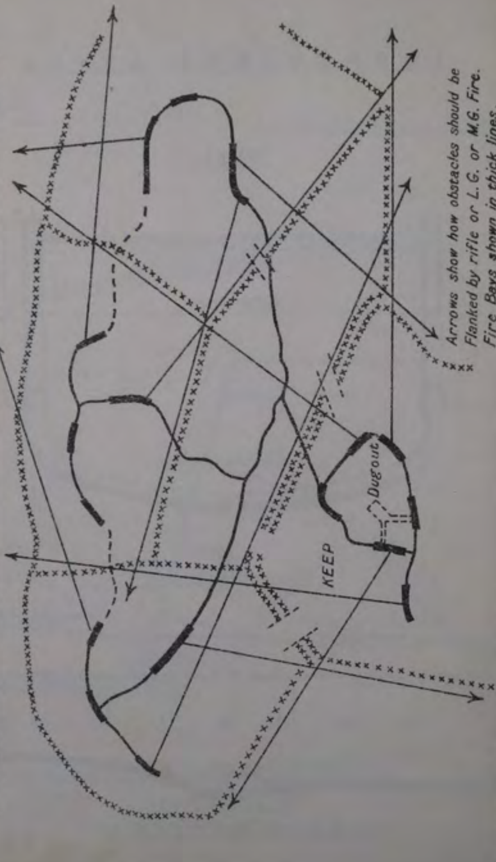


Fig. 2.

SIDE ELEVATION.

[See Sec. 19, 5.

DEFENDED LOCALITY IN ISOLATED POSITION FOR 4 PLATOONS.



Arrows show how obstacles should be Flanked by rifle or L.G. or M.G. Fire. Fire Bays shown in thick lines.

See Sec. 19, 5.]

TYPES OF DEFENDED POSTS.

FOR 1 SECTION.

FIG. 1.

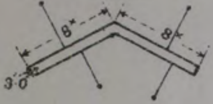


FIG. 2.

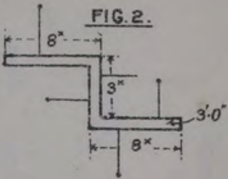


FIG. 3.

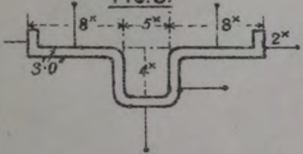


FIG. 4.

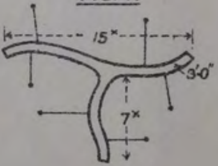
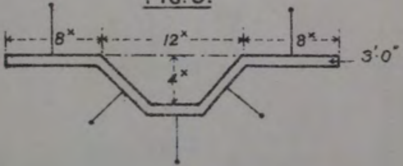


FIG. 5.



These posts which at first are 3'×3' can be widened and deepened to the section given in Fig. 3 Plate 48 and connected by communication trench into Platoon Posts, as time becomes available.

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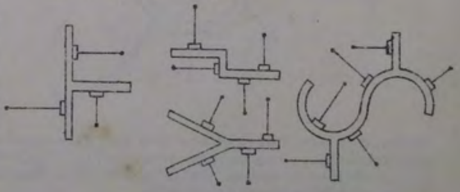
DEFENDED POSTS AT JUNCTION OF TRENCHES.

METHODS OF PRODUCING ALL ROUND FIRE.



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See Sec. 24.]

DEFENCE OF A VILLAGE.

ORGANIZED AS A DEFENDED LOCALITY, I COY.

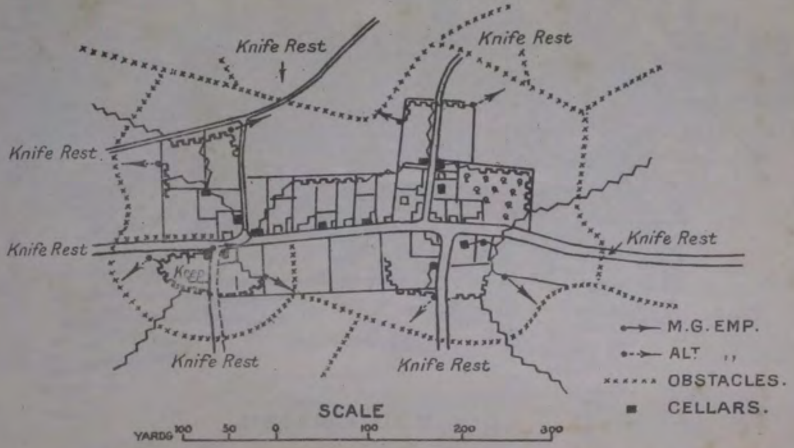

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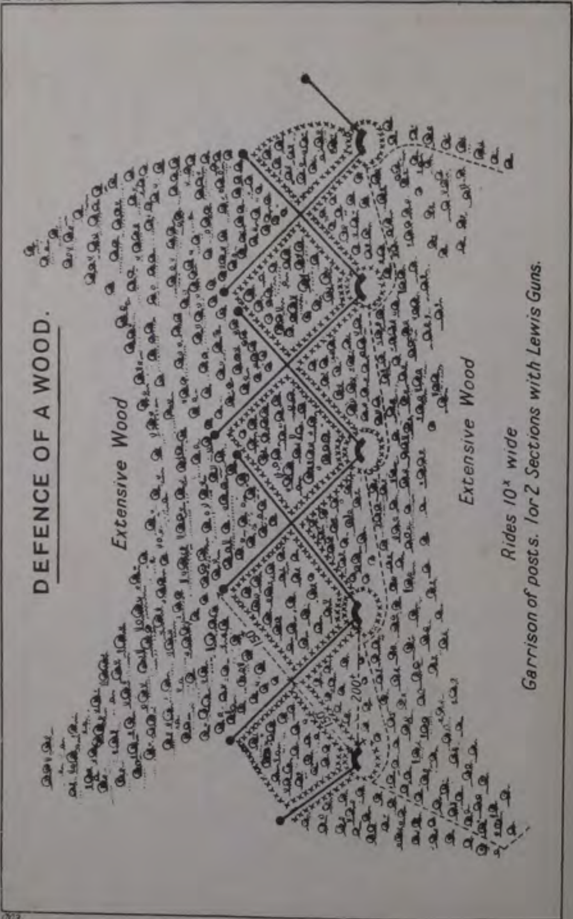
Plate 17.



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[See Sec. 25.]

Plate 19.

OBSTACLES AND CLEARING IN A WOOD.

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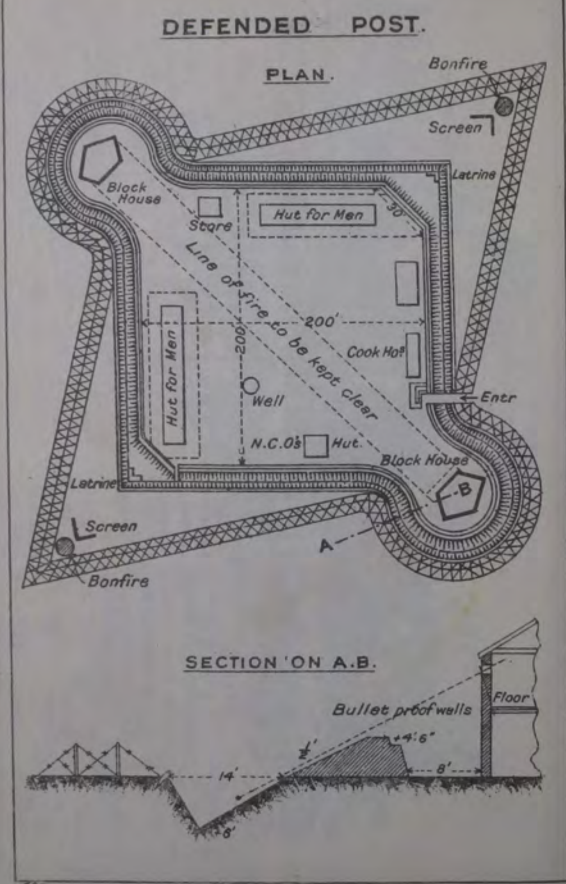

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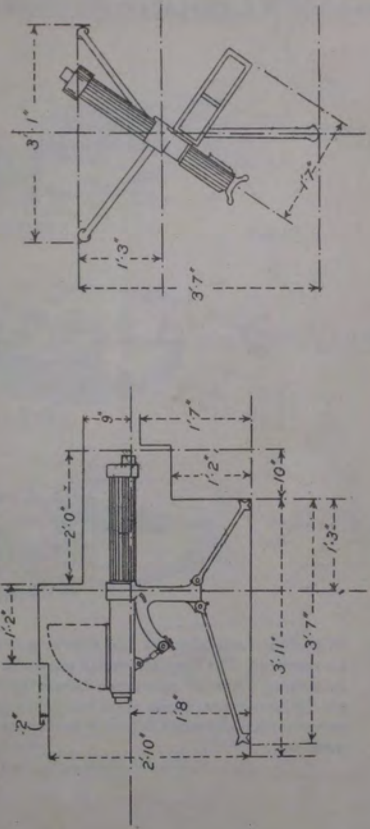
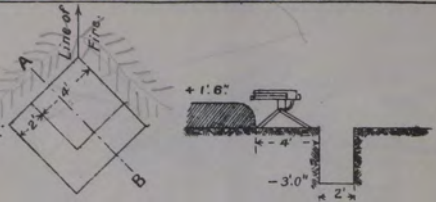
MINIMUM DIMENSIONS OF NORMAL M.G. EMPLACEMENT.



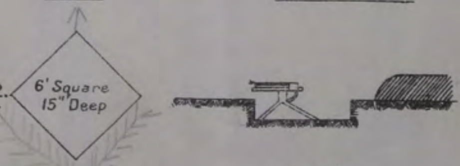
TYPES OF M.G. EMPLACEMENTS IN OPEN GROUND.

Fig. 1.



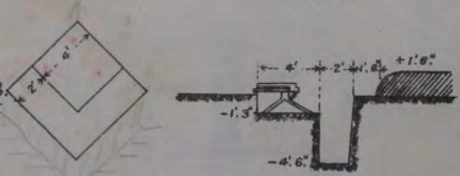
PLAN SECTION A.B.

Fig. 2.



PLAN SECTION

Fig. 3.



When time is available the Gun Platform in Fig.3. should be revetted. The Emplacements may also be connected by cutting a trench rearwards from the rear angle of the Emplacement, these trenches joining a lateral communication trench & giving access to the control post etc.

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SHELL-HOLE M.G. EMPLACEMENT.

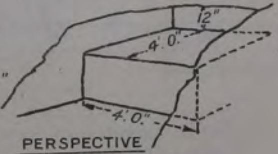
Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.



PERSPECTIVE

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CONCEALMENT OF M.G. EMPLACEMENT.

Fig. I.

Fig. 2.

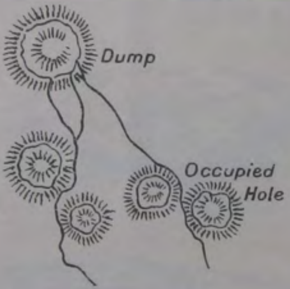
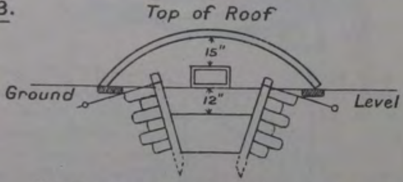


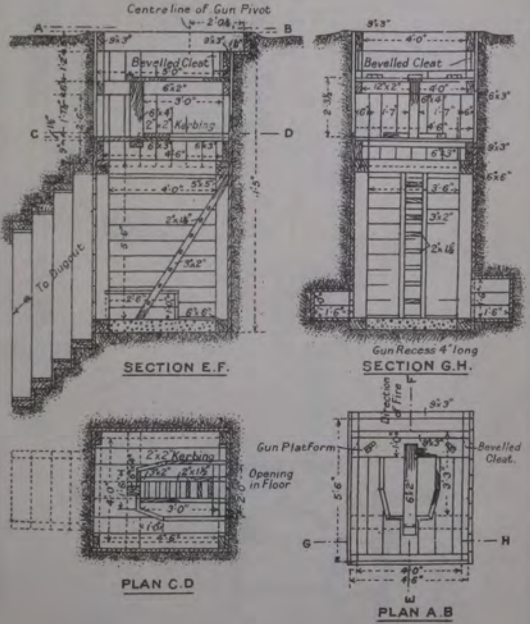
Fig. 3.



Emplacement with Splinter-proof Roof
(*Material on top of Roof not shown*)

M. G. EMPLACEMENT DETAILS.

(CHAMPAGNE TYPE)



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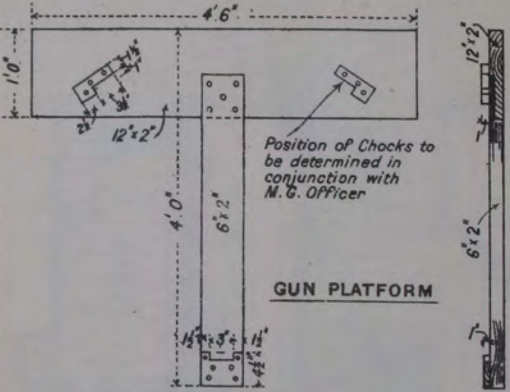
[See Secs. 32, 1; 33, 3.

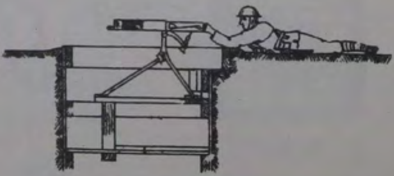
DETAILS OF "T-BASE" FOR AN OPEN MACHINE GUN PLATFORM



GUN PLATFORM

PLAN

SECTION



SKETCH

Showing Gun being fired from reverse position.

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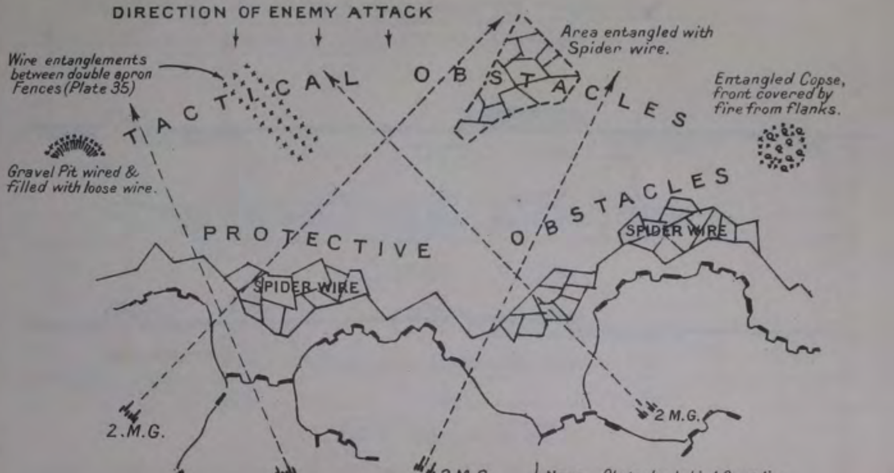
See Sec. 34.

EXAMPLE SHOWING PROTECTIVE & TACTICAL OBSTACLES (DIAGRAMMATIC ONLY)



NOTE. *Obstacles behind front line of Posts not shown.*

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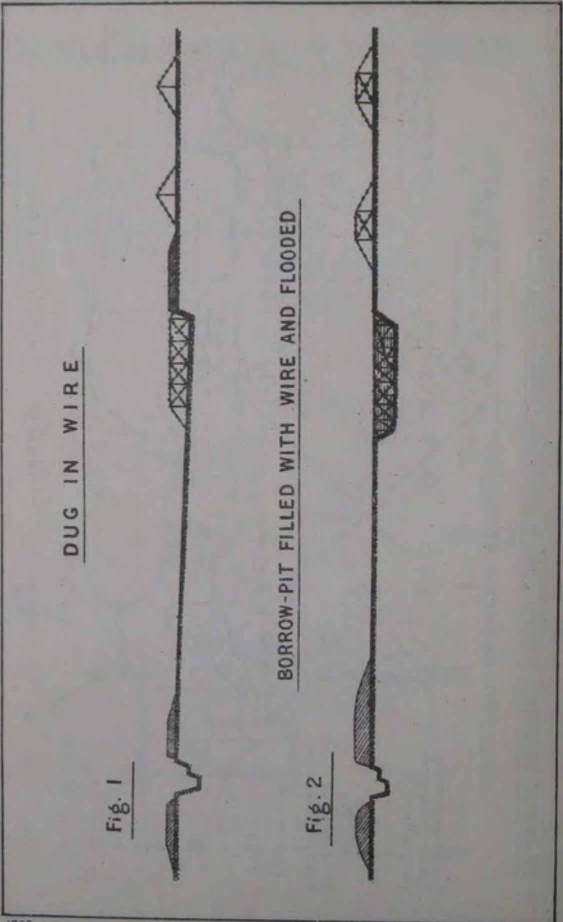
Plate 27.



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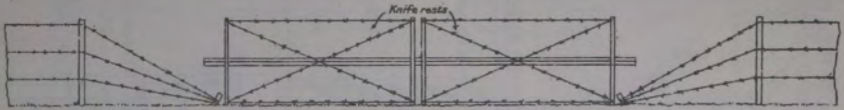
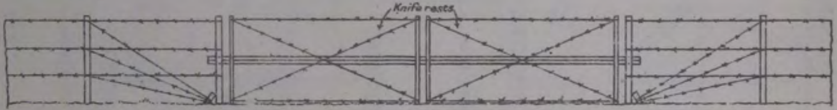
See Sec. 35, 1.]

DIAGRAM SHOWING HOW TO FINISH OFF THE ENDS OF THE ENTANGLEMENT AT A GAP.



WRONG.



RIGHT

NOTE. *Knife Rests must be securely anchored to the entanglement and to each other.*

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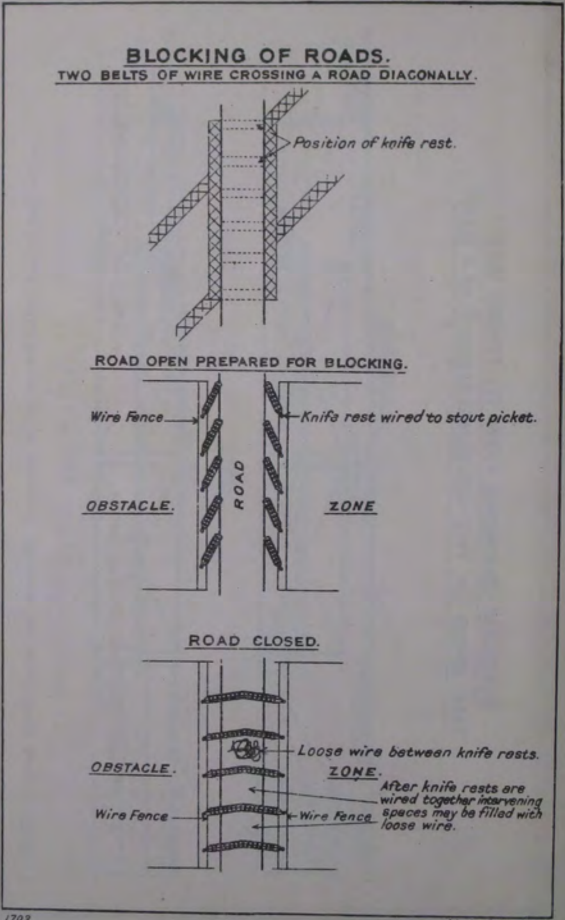
Plate 29.

[See Sec. 35, 2.



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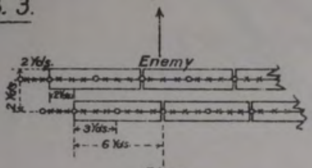
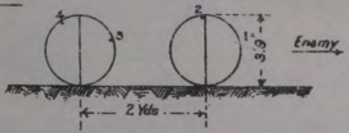
DOUBLE BELT OF CONCERTINAS.

Fig. 3.



Plan.

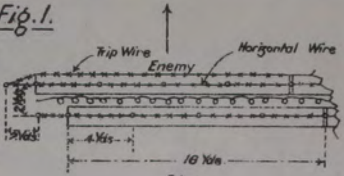
Fig. 4.



Section. (Enlarged)

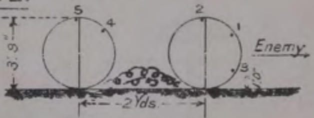
WIRE ENTANGLEMENT. (FRENCH).

Fig. 1.



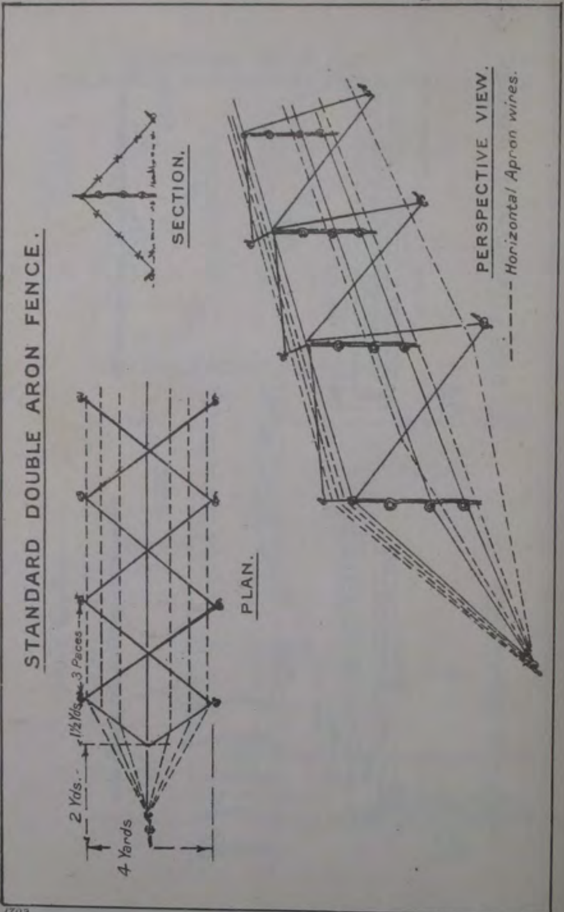
Plan.

Fig. 2.



Section (Enlarged)
Order of putting on wires.

STANDARD DOUBLE ARON FENCE.



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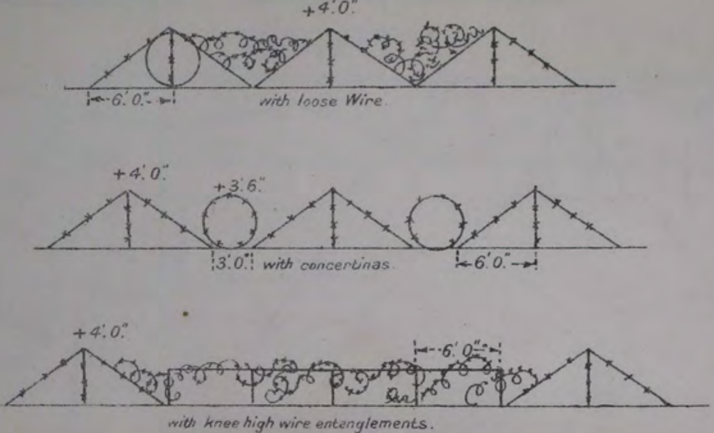
DOUBLE APRON ENTANGLEMENT.

AS FRAMEWORK FOR WIDE OBSTACLES.



See Secs. 37, 5; 40, 1.]

Plate 33.

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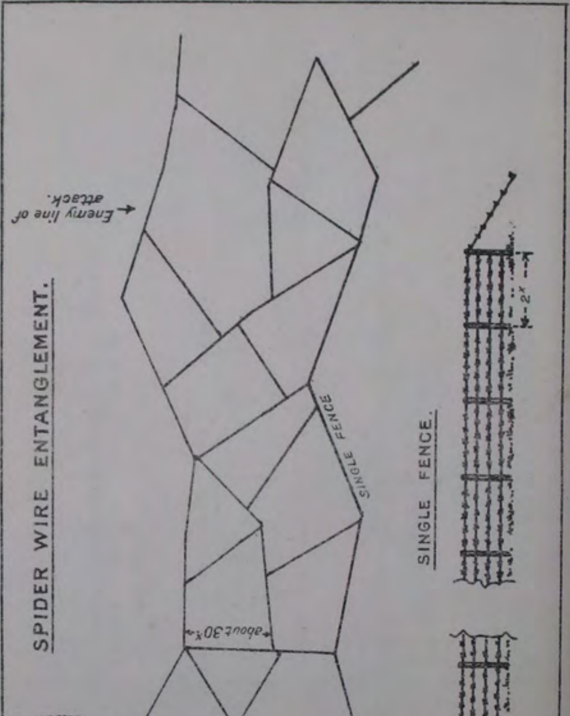

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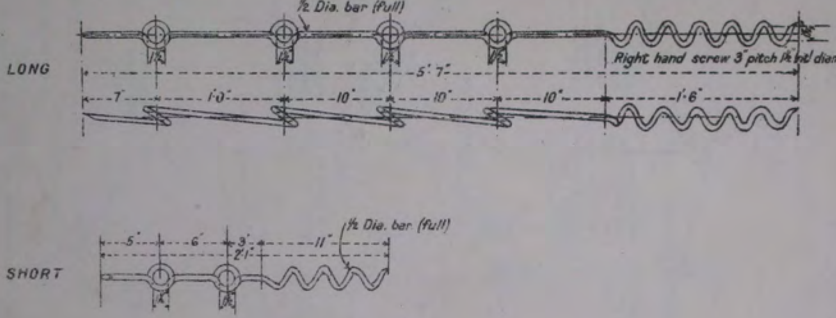
SCREW PICKETS FOR WIRE ENTANGLEMENTS

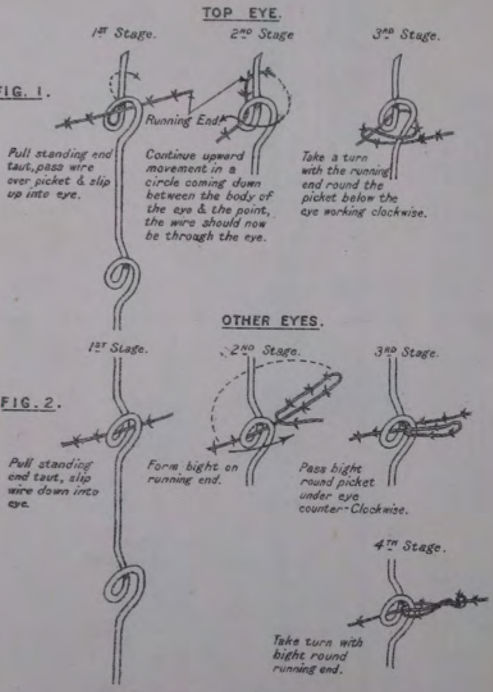


See Sec. 38, 5.

METHOD OF FIXING WIRE TO PICKETS.

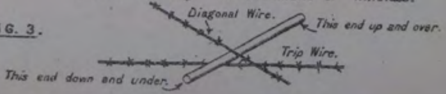
FIG. 1.

FIG. 2.

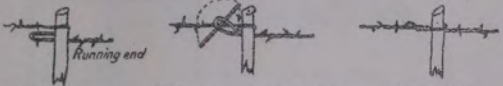


Sketch showing commencement of Windlass.

FIG. 3.



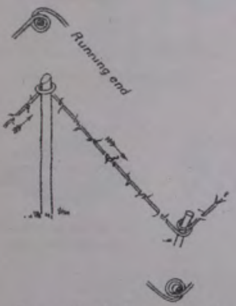
METHOD OF FIXING WIRE ON POSTS.



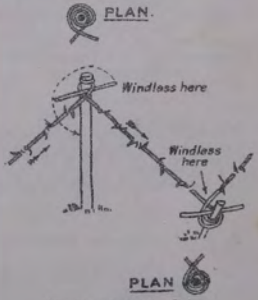
1st Sketch showing Bight

2nd Operation showing position ready for windlassing with Iron Bar

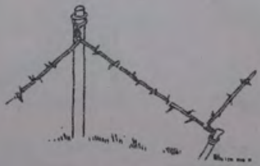
3rd Operation Completed



Wrong method for fixing diagonal wire on wood posts and pickets

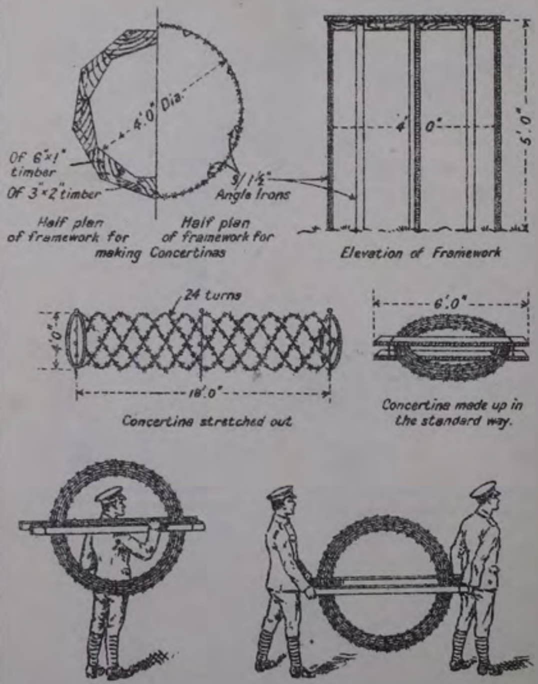


Correct method for fixing diagonal wire on wood posts and pickets ready for windlassing with iron bar.



After Windlassing

BARBED WIRE CONCERTINAS.



Half plan of framework for making Concertinas

Half plan of framework for making Concertinas

Elevation of Framework

Concertina stretched out

Concertina made up in the standard way.

Sketch showing one man carrying Concertina on shoulder.

Sketch showing two men carrying Concertina.

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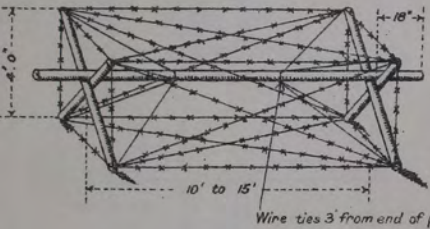
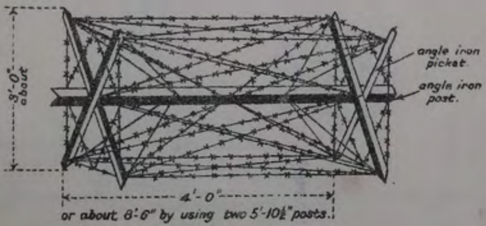
Knife Rests.

Large Knife Rest Made of Wood



Knife Rest Made of Iron Pickets.



[*See Sec. 42, 2.*

BARRICADES.

FIG. 1.

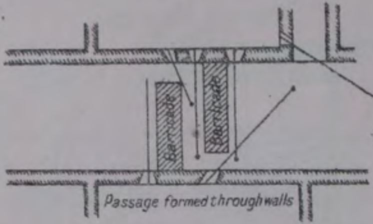
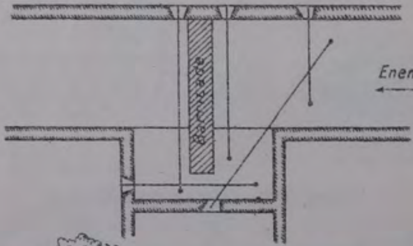


FIG. 2.



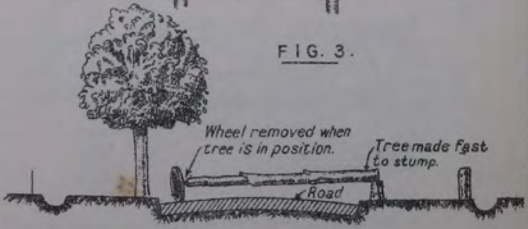


FIG. 3.

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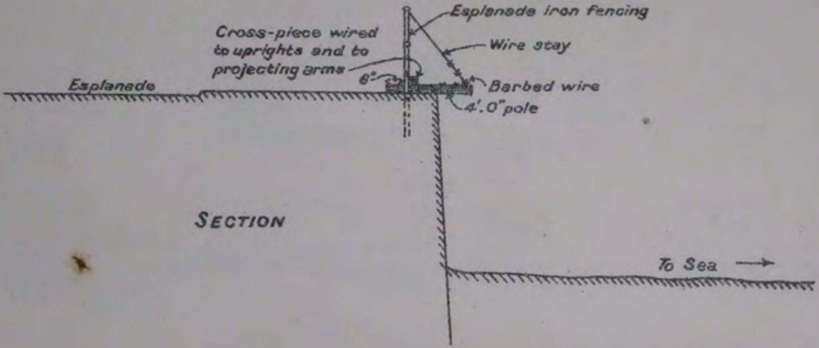
TYPE OF OBSTACLE ON ESPLANADE RETAINING WALL.



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See Secs. 29, 7, iv; 42, 3.]

Plate 41.

[See Secs. 44, 2 and 6; 45, 1 and 2

1708.

THE SITING OF TRENCHES.

FIG. 1.

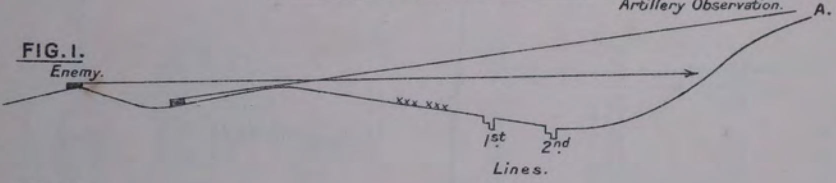


FIG. 2.

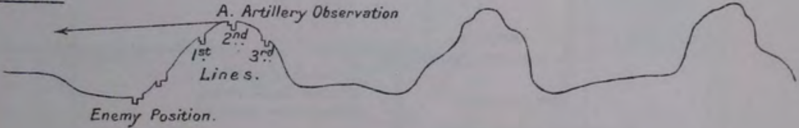
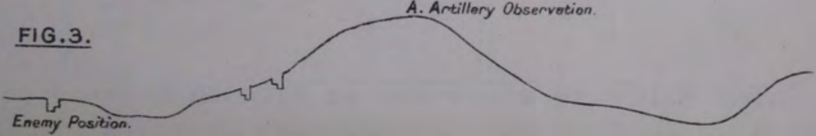
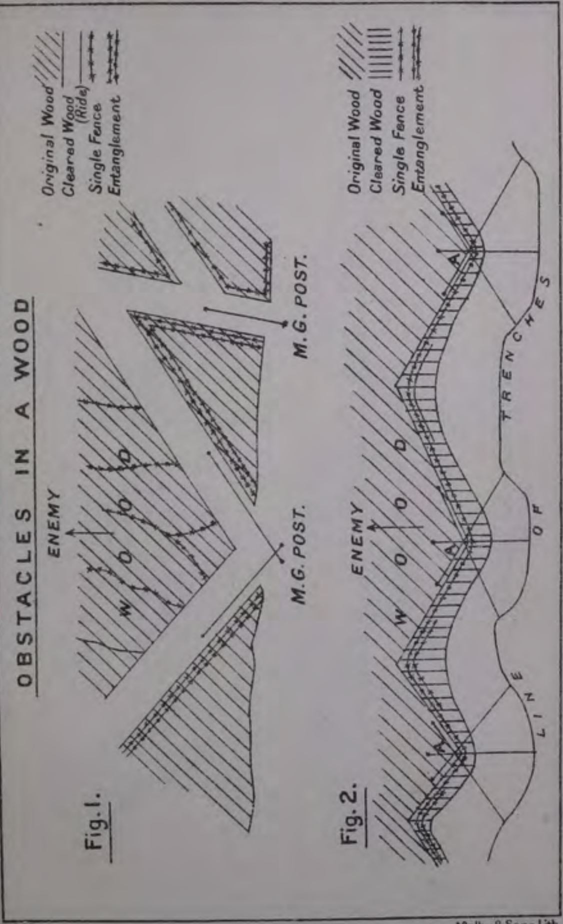


FIG. 3.



Malby & Sons, Lith.

OBSTACLES IN A WOOD



TRACE OF TRENCHES

Fig. 1.

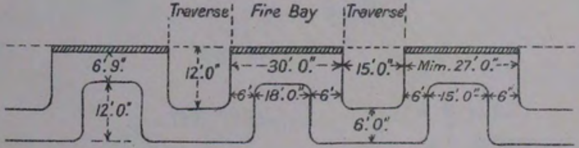
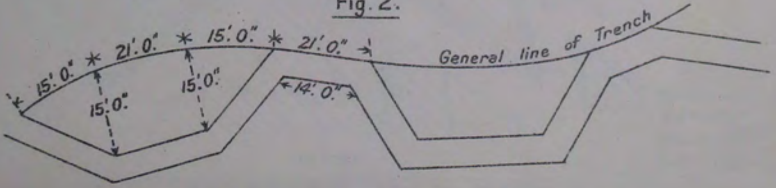


Fig. 2.



[See Secs. 13, 3; 50, 1 and 3.

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See Secs. 18, 3; 50, 3, iii.]

TRACE OF TRENCHES.

FIG. 1.

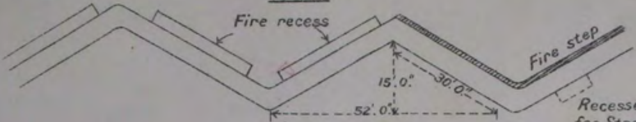
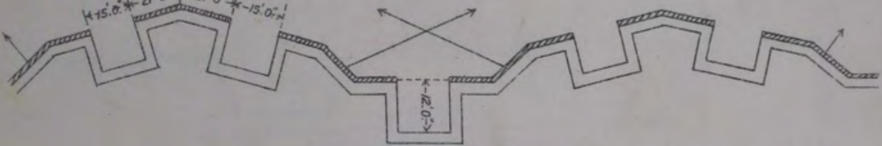


FIG. 2.



Showing application of various forms of trace to the ground.

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[See Secs. 13, 3; 50, 3, iii; 51, i.

ALTERNATIVE TRACE OF TRENCHES.

FIG. 1.
OCCASIONAL FORWARD TRAVERSE

Provides a good position for a snipers post or position for a machine gun for flanking fire

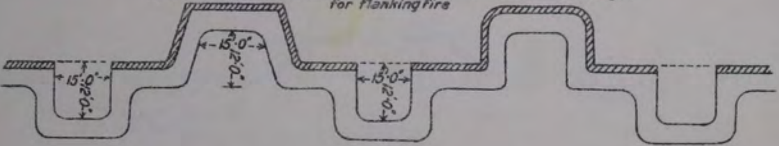


FIG. 3.

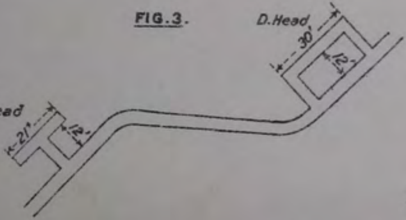
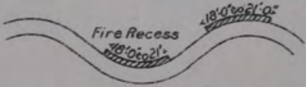


FIG. 2.



CURVED WITHOUT TRAVERSES

A traversed trench is the better but takes longer to dig

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ALTERNATIVE TRACE OF TRENCHES

FIG. I.
DOG LEGS.

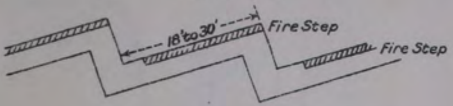
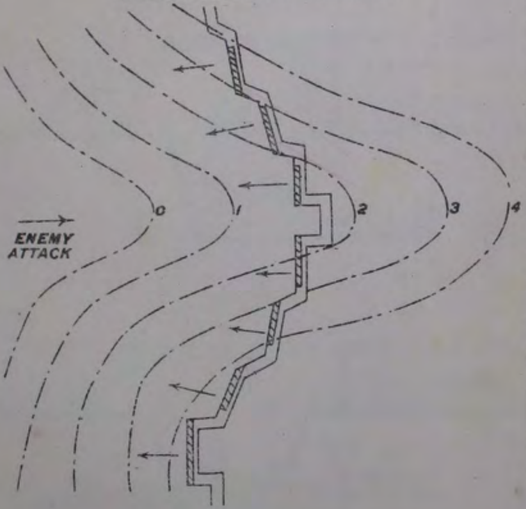


FIG. 2.
EXAMPLE OF USE OF DOG LEGS.



NORMAL SECTION OF FIRE TRENCH.

Fig. 1.

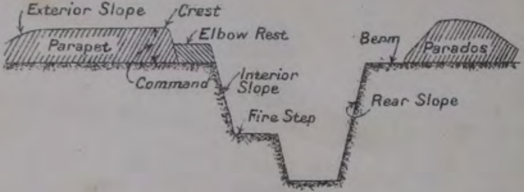


Fig. 2. ORDER OF WORK.

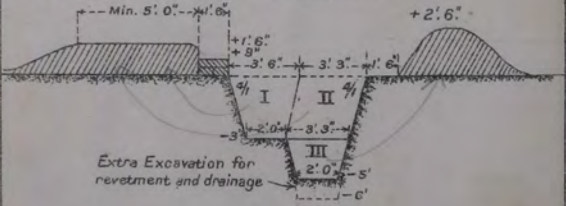
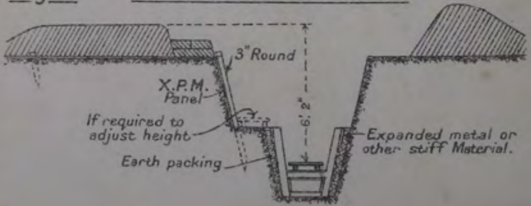


Fig. 3. FINAL SECTION OF TRENCH.



See Sec. 51, 1 and 2.]

DEFENCE OF FIRE TRENCH AGAINST BOMBING.

FIG. I.

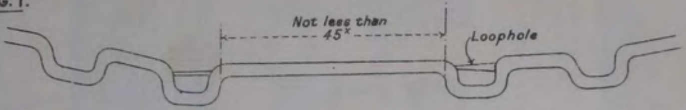
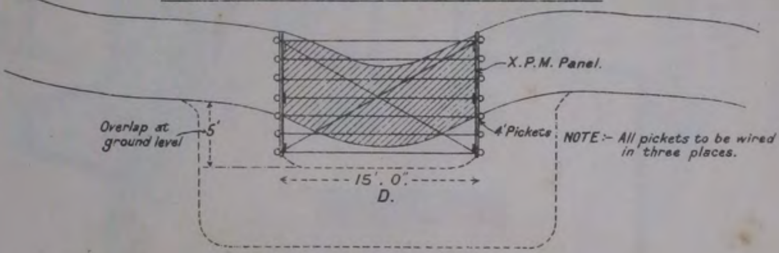


FIG. 2.

TRAVERSING AN UNTRAVERSED TRENCH.



PLAN AT GROUND LEVEL.

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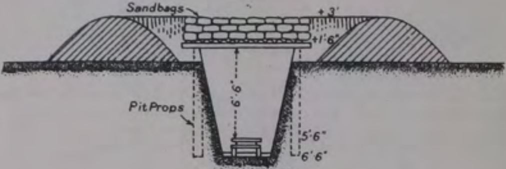
[See Sec. 51, 3.

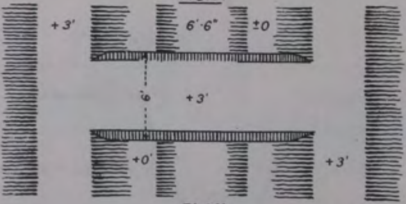
BRIDGE TRAVERSE

FIG. 1.



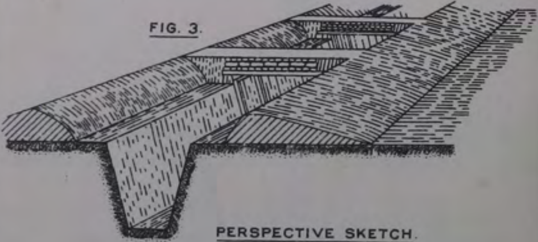
ELEVATION

FIG. 2.



PLAN

FIG. 3.



PERSPECTIVE SKETCH.

1703.

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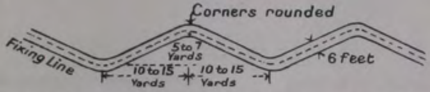
TRACE & SECTION OF COMMUNICATION TRENCH

Fig. 1.
TRACE



The bends in the trench must conform to the ground so as to get the best advantage in cover, but roughly the distance between bends should not be more then 15 yards up to reserve trenches and not more than 10 yards between reserve and fire trenches.

Fig. 2.
REVETTED SECTION

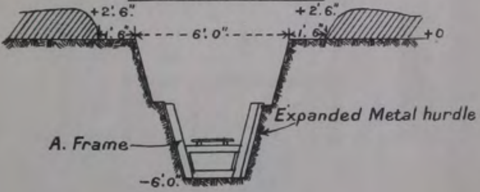
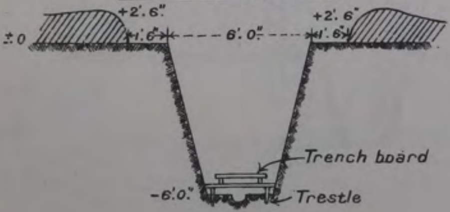


Fig. 3.
UNREVETTED SECTION



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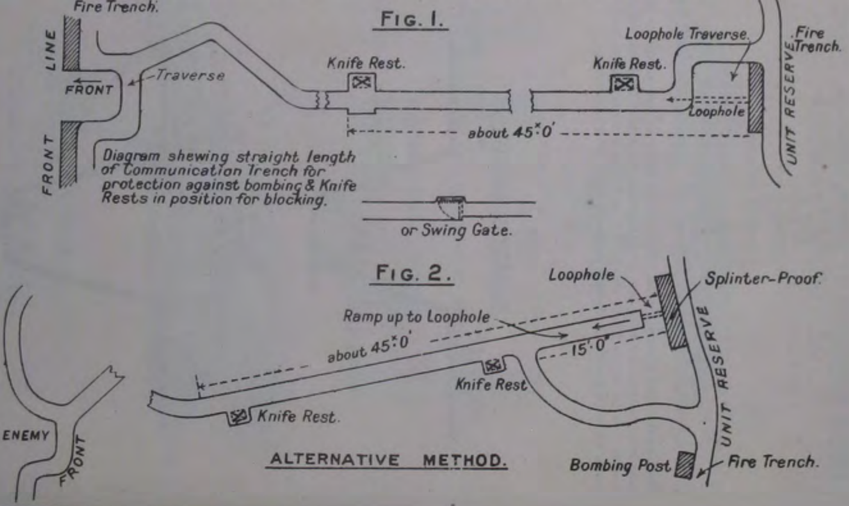
METHODS OF DEFENCE OF COMMUNICATION TRENCHES.



ALTERNATIVE METHOD.

[See Sec. 52, 4.

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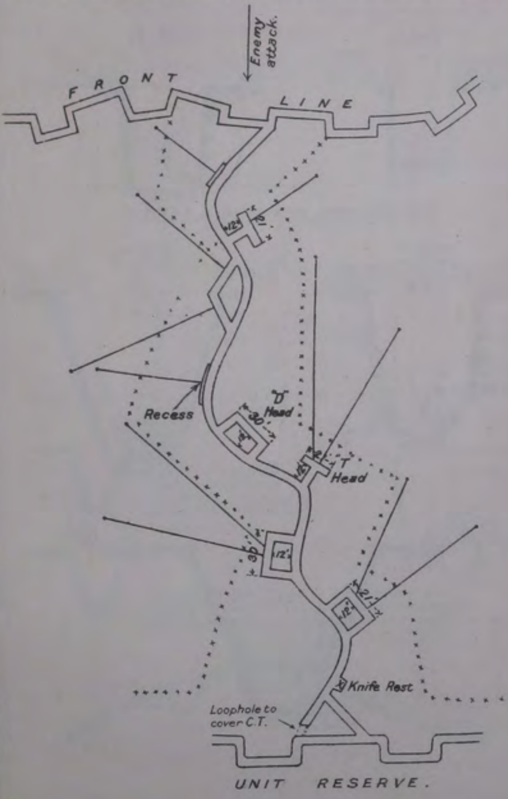
DEFENCE OF COMMUNICATION TRENCH BY "D" HEADS, "T" HEADS AND RECESSES.



SHELL SLITS

TO GIVE QUICK IMPROVISED SHELTER

FIG. 1.

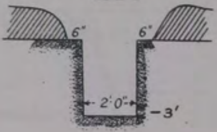
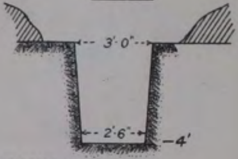


FIG. 2.



METHOD OF REPAIRING A TRENCH

FIG. 3.

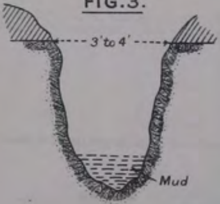


FIG. 4.

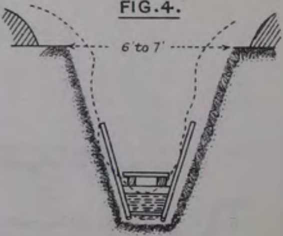
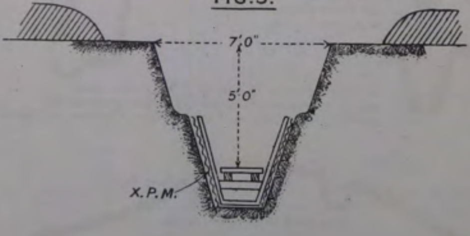


FIG. 5.



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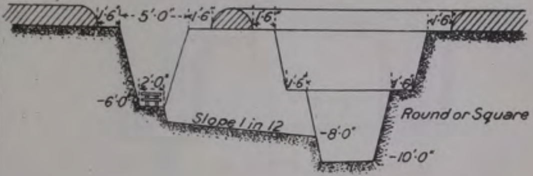
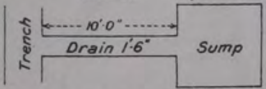
TYPE OF SUMP.

SECTION.

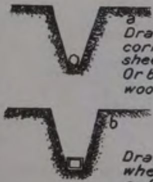


PLAN

Sump consists of a circular or square hole revetted if necessary

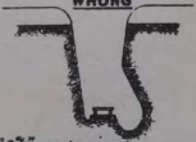


Note:- Sump should never be put in where drainage out to lower ground can be arranged.

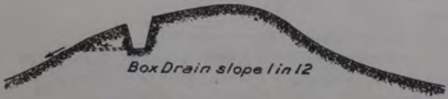


Drain formed of corrugated iron sheets (a).
Or boxed (lined with wooden box (b).

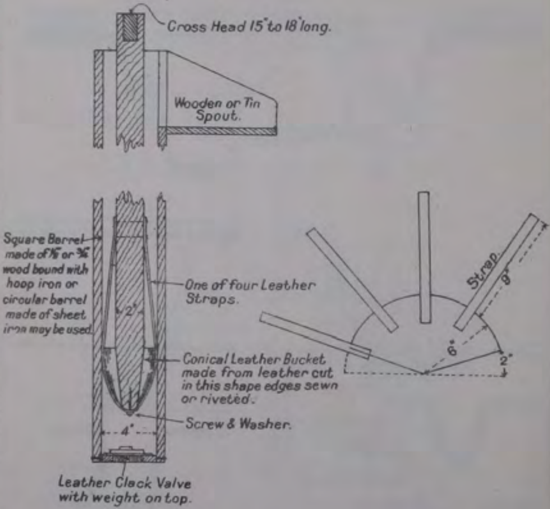
WRONG



Drains of the Types "a" & "b" can be used when a trench is sited on sloping ground sufficient to ensure the flow of water as below.



SLUDGE PUMP.



The pump must be primed before working.
On the upward stroke the weight of the water forces the leather of the bucket against the sides of the barrel, while the straps prevent the bucket collapsing.
On the downward stroke the water is forced between the bucket & the sides of the barrel.
The pump is not useful for more than a 6 foot lift.
For emptying trenches the barrel may be made with an 8" or 9" side, & the pump will discharge any solids small enough to pass through the clack valve and between the plunger and the barrel.

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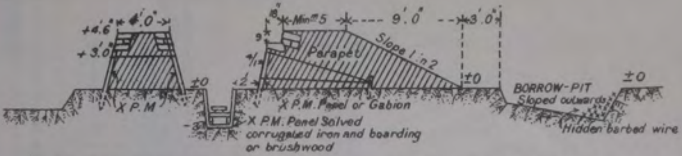
SECTION OF BREASTWORK IN WET SOIL.

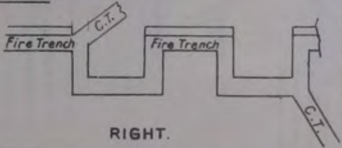
FIG. I.



NOTE *Depth of bottom to vary according to ground. Set frames as low as possible. to save breastwork. Drainage at grade of 1/100 to lower ground essential.*

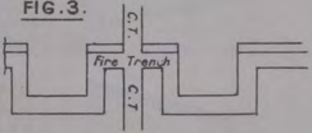
COMMUNICATION TRENCH CROSSING A FIRE TRENCH.

FIG. 2.



RIGHT.

FIG. 3.



WRONG.

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[See Secs. 52, 5; 61.]

SAPPING

FIG. 1.

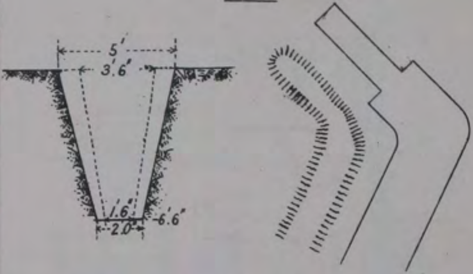
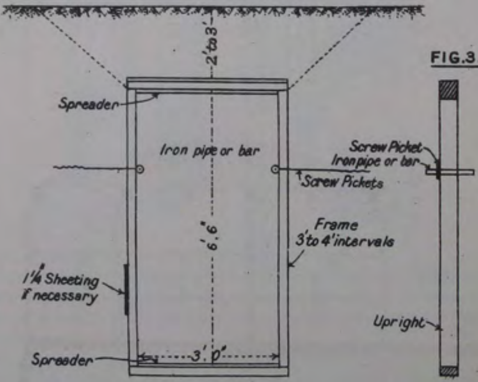


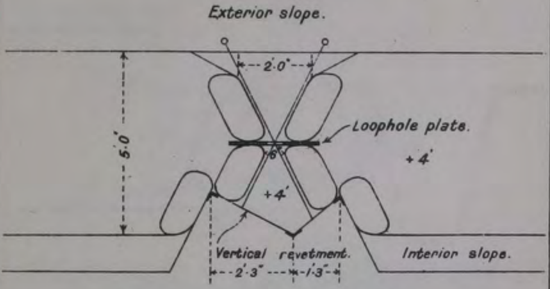
FIG. 2. RUSSIAN SAP

FIG. 3.



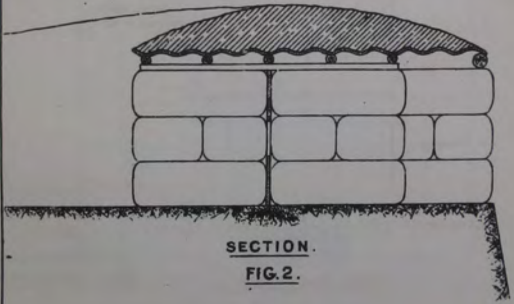
END ELEVATION SIDE ELEVATION

LOOPHOLES.



PLAN AT LEVEL 4 FEET SHOWING FIRST LAYER OF SANDBAGS FORMING LOOPHOLE

FIG. I.



SECTION.

FIG. 2.

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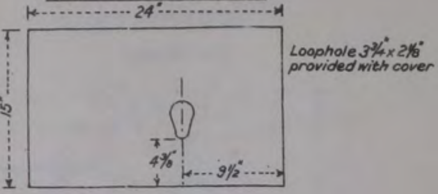
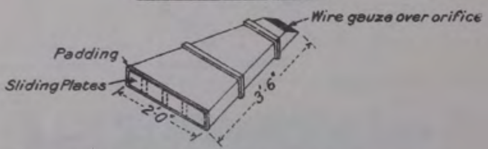
LOOPHOLE PLATE.

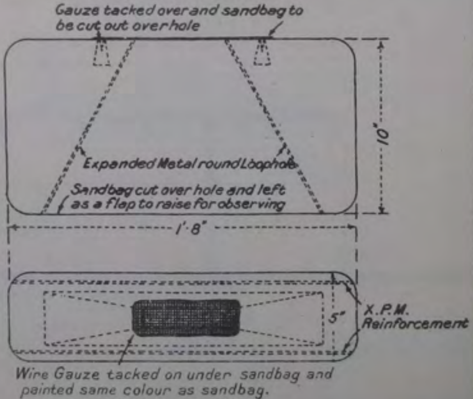


LOOPHOLE BOX.



MOCK SANDBAG CEMENT LOOPHOLE.

FOR OBSERVATION



FINISHED ARTICLE.

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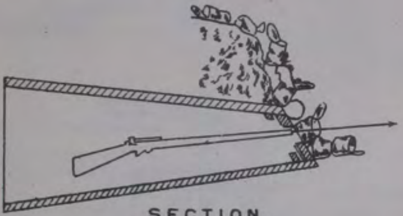
SNIPER'S POST.

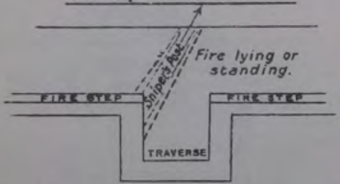


SECTION.

VIEW FROM FRONT.

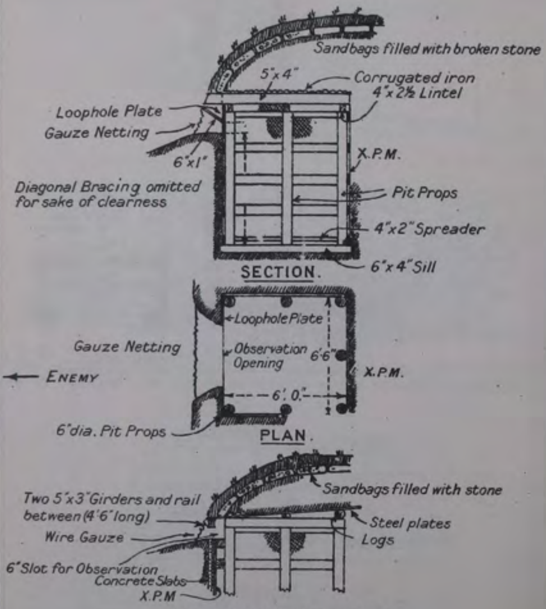
When front parapet is covered with tins of all kinds, the tin used to disguise the loophole is very difficult to identify even at 10 yds. range.

OBLIQUE LOOPHOLE.



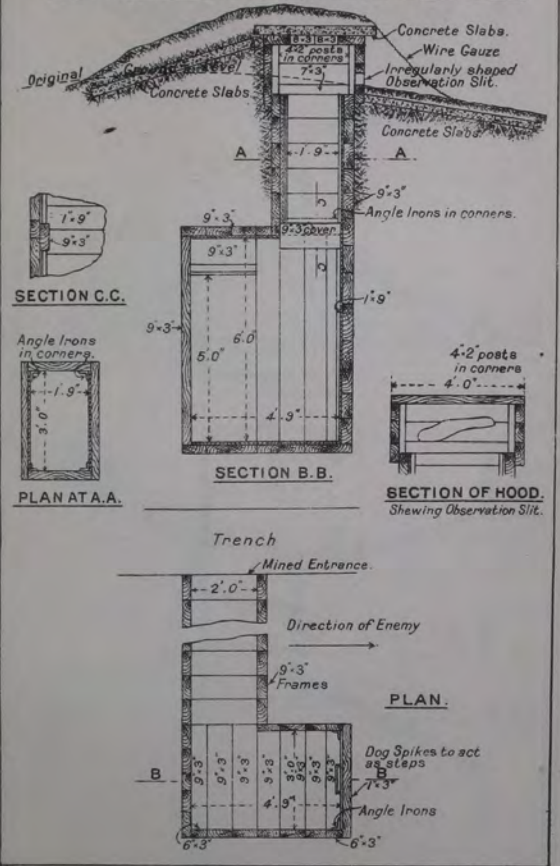
Plenty of Dummy Loopholes should be provided.

SPLINTER AND BULLET PROOF OBSERVATION POST.



ALTERNATIVE HEAD PIECE.

SPLINTER PROOF OBSERVATION POST.



1703.

METHOD OF SLOPING THE SIDES OF A TRENCH.

RIGHT

FIG. 1.

WRONG

FIG. 2.

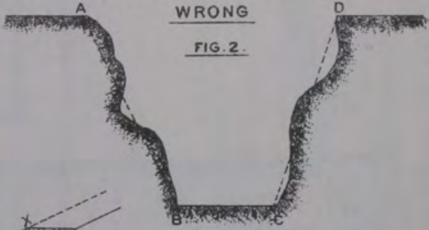
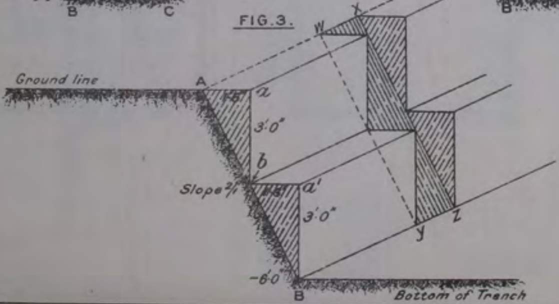


FIG. 3.



[See Sec. 60.1.

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ANCHORAGES.

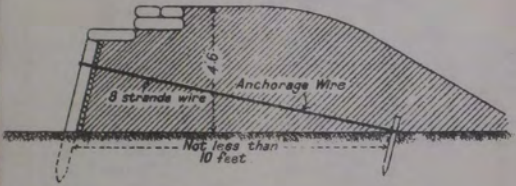


FIG. I
BREASTWORK.

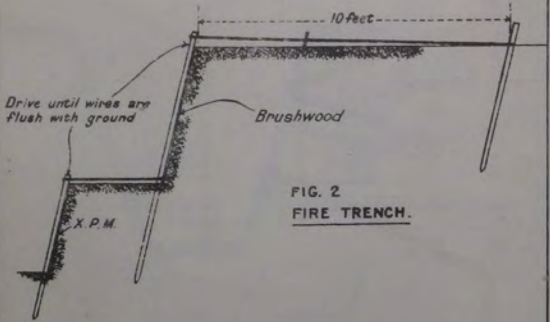


FIG. 2
FIRE TRENCH.

Malby & Sons Lith.

See Secs. 60, 4, i; 74, 10.

REVETMENT ANCHOR

FIG. 1.

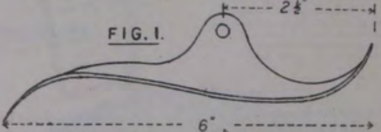
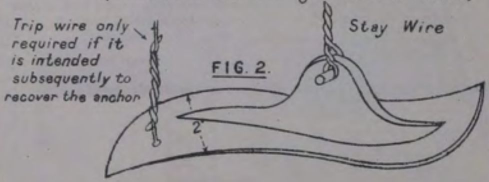
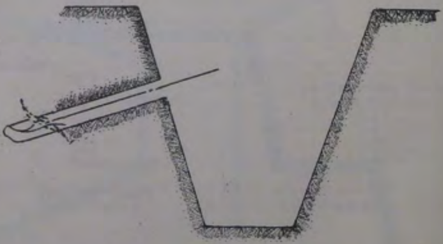


FIG. 2.

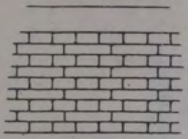




Malby & Sons Lith.

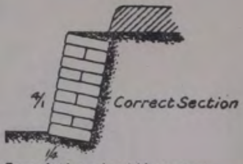
SANDBAG REVETMENT.

ELEVATION

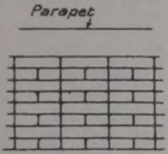


Correct
English Bond
Seams and Choked Ends on
Parapet Side of Revetment.

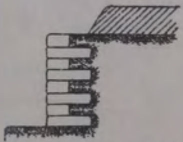
SECTION



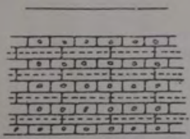
Foundation should be cut at right angles to slope and always brought to a solid bottom.



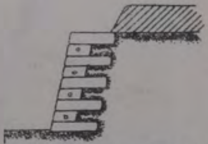
Wrong (Joints not Broken)



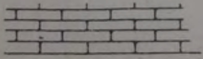
Wrong (Vertical)

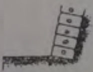


Wrong (Seams and Choked Ends of Bags outward).



Wrong (Bags not at Right Angles to Slope).





Wrong (All Stretchers and no Headers).

1702 Malby & Sons, Lith.

1702.

Plate 68.

ADAPTATION OF HEDGES AND WALLS.

FIG. 1.

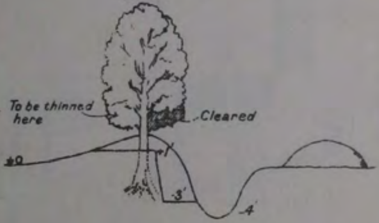
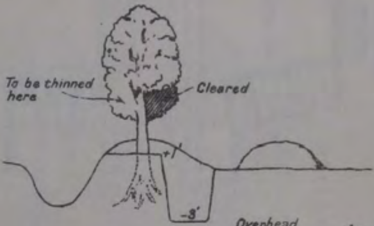


FIG. 2.



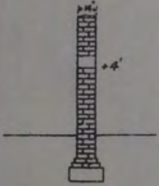


FIG. 3.

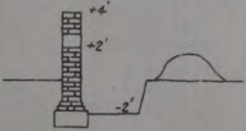


FIG. 4.

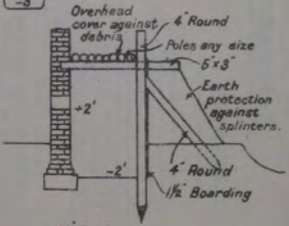


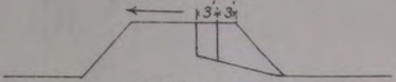
FIG. 5.

See Sec. 62.

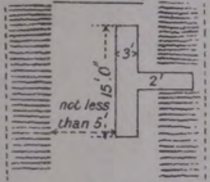
Malby & Sons, Lith.

ADAPTATION OF CUTTINGS AND EMBANKMENTS.

EMBANKMENT

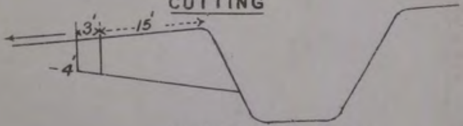


SECTION

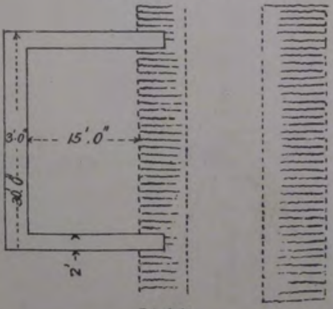


PLAN

CUTTING



SECTION



PLAN

1703.
Malby & Sons Lith.

See Sec 64. 3

DEFENCE OF A HOUSE.

(Not exposed to Artillery Fire.)

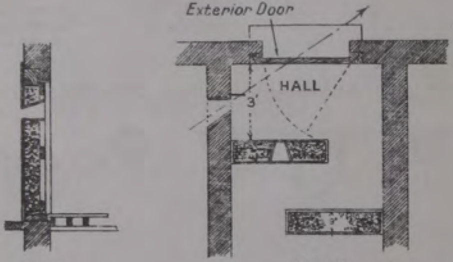


FIG. 1.

FIG. 2.

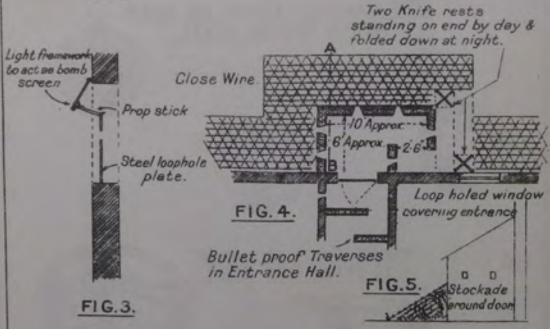


FIG. 3.

FIG. 4.

FIG. 5.

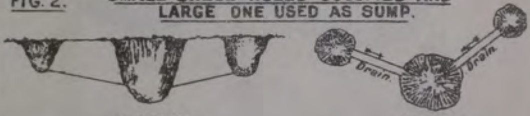
SECTION A.B.

Malby & Sons, Lith.

IMPROVEMENTS TO SHELL-HOLES.

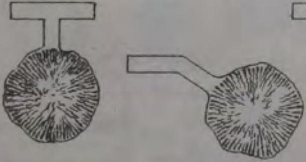
FIG. I.

FIG. 2. SMALL SHELL-HOLES OCCUPIED AND LARGE ONE USED AS SUMP.



SECTION. PLAN.

FIG. 3. NO EXCAVATED EARTH TO SHOW ABOVE GROUND LEVEL.



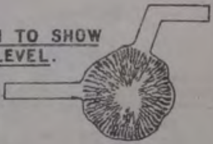
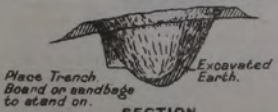


FIG. 4. FRONT FACE CUT AWAY TO FORM FIRE STEP.

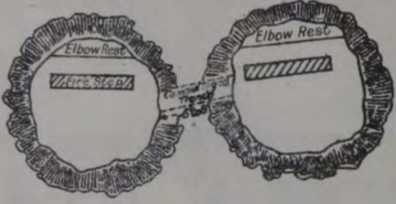


SECTION.

PLAN.

TWO SHELL-HOLES WITH CAMOUFLAGED CONNECTION.

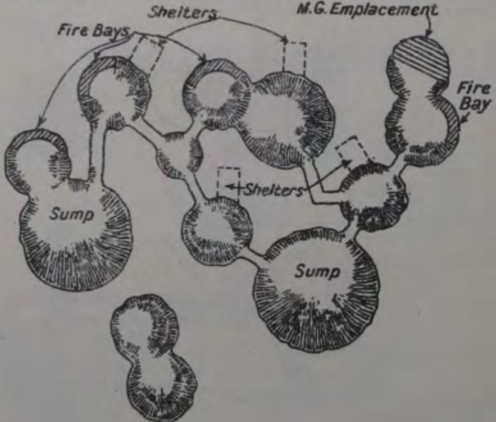
Fig. 1.



PLAN

Fig. 2.

SHELL-HOLE POSITION



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IMPROVEMENTS TO SHELL-HOLES.

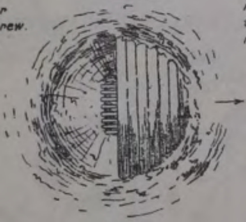
FIG. I.

Lip of shell-hole not to be disturbed.

SECTION.

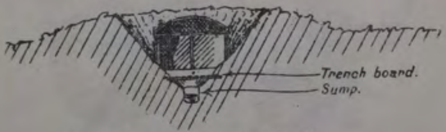
Weather-proof cover for Lewis gun and crew. Gun fires from top of shelter.

All excavated earth to be dumped in neighbouring holes.



PLAN.

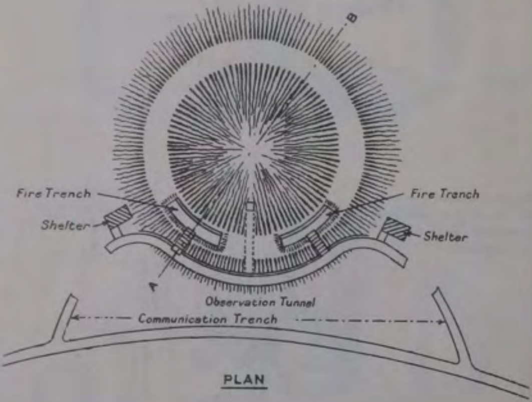
FIG. 2.



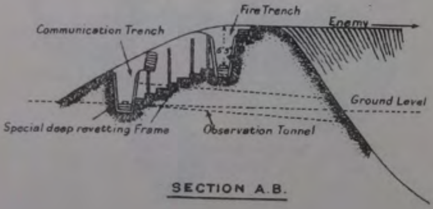
Showing shelter let into side of shell-hole. roof of curved sheets of C. I.

DEFENCE OF CRATERS.

NEAR LIP DEFENDED.



PLAN



SECTION A.B.

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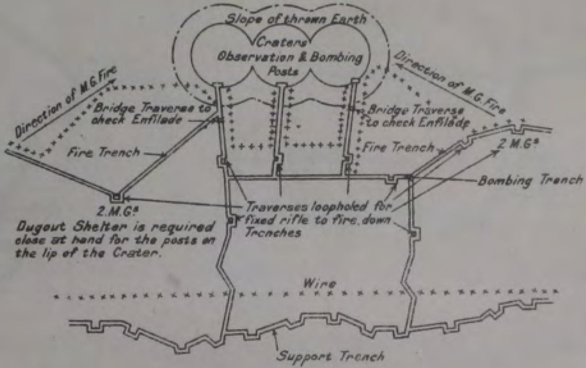
1703

DEFENCE OF CRATERS.

BY BOMBING TRENCHES WHERE THERE IS NO FIELD OF FIRE.



See Secs 65, 2

Plate 77.

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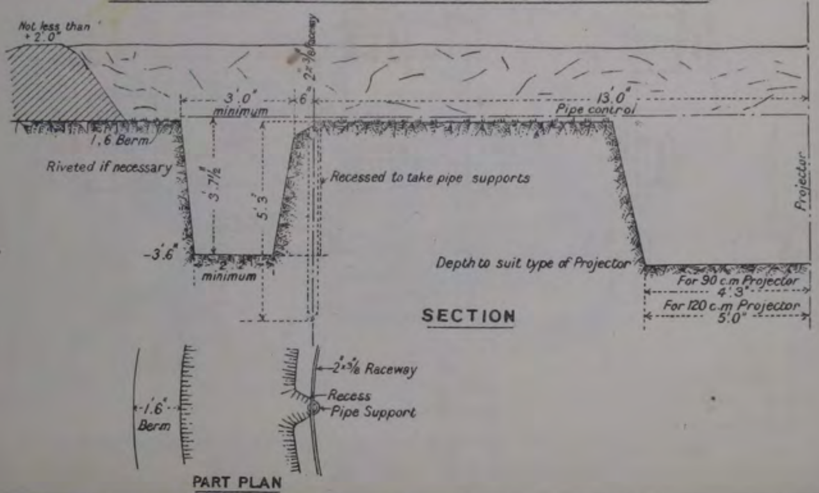
TYPE OF SEARCHLIGHT EMPLACEMENT
SUITABLE FOR SKEW GEAR PIPE CONTROL WITH TELESCOPE.



1708.

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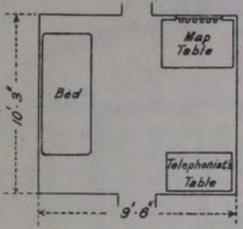
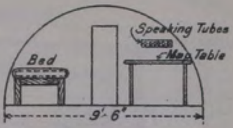
[See Sec. 67.

BATTERY COMMAND POST.

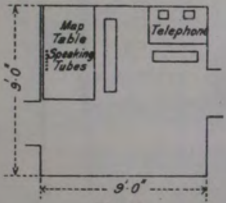


PLAN.



SECTION.

FIG. 1.

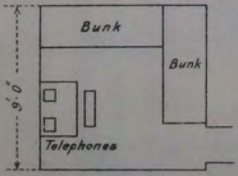


PLAN.

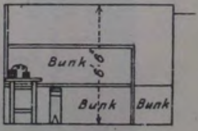
SECTION.

FIG. 2.

TELEPHONE DUG-OUT.



PLAN.



SECTION.

FIG. 3.

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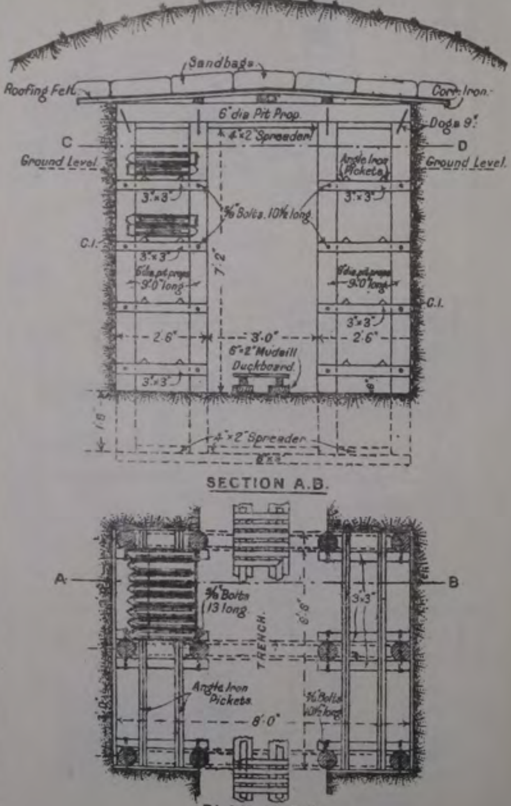
18-POUNDER AMMUNITION SHELTER.

(FOR DRY GROUND.)



SECTION A.B.

PLAN AT C.D.

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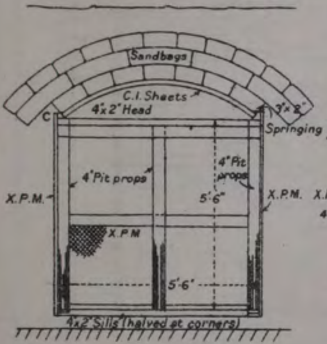
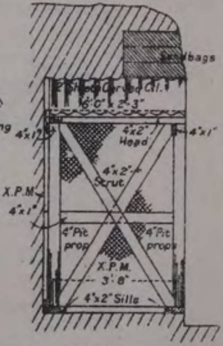
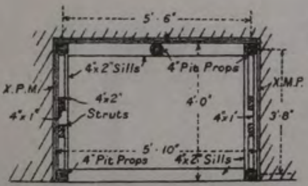
SPLINTER-PROOF RECESS FOR AMMUNITION.



FRONT ELEVATION



SECTION.

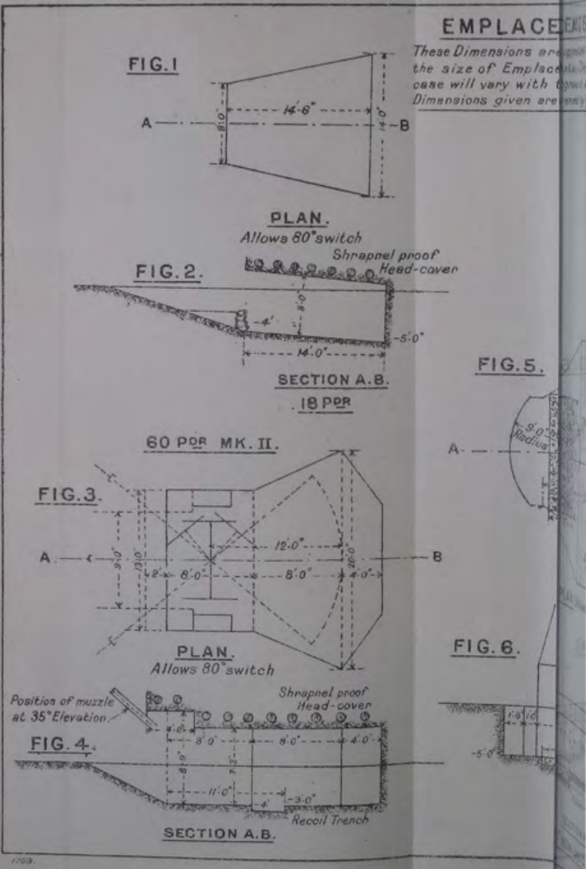


PLAN.

DETAIL "C"

Shelves for ammunition etc. must not be supported on the framework of the recess.

See Sec. 68, 6.]

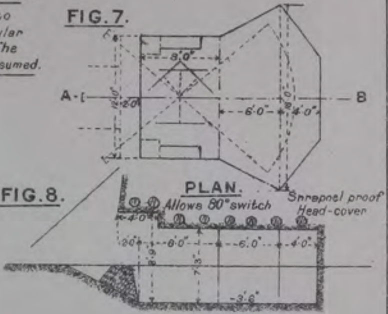

EMPLACE
These Dimensions ar
the size of Emplace
case will vary with
Dimensions given are
FIG. 1
14'6"
8'0"
14'0"
A
B
PLAN.
Allows 80° switch
FIG. 2.
Shrapnel proof
Head-cover
8'0"
4'
5'0"
14'0"
SECTION A.B.
18 PDR
60 PDR MK. II.
FIG. 3.
12'0"
9'0"
13'0"
2'
8'0"
8'0"
20'0"
4'0"
A
B
PLAN.
Allows 80° switch
FIG. 4.
Position of muzzle
at 35° Elevation
Shrapnel proof
Head-cover
8'0"
8'0"
4'0"
8'9"
7'3"
11'0"
4'
3'0"
Recoil Trench
SECTION A.B.
FIG. 5.
9'0" Radius
A
FIG. 6.
5'0"
1703.

E…ENTS, (ARTILLERY).

…re …ggested as a general guide to …cem…ts. The details in any particular …th…round and other factors. The …e g…rned by the angle of switch assumed.

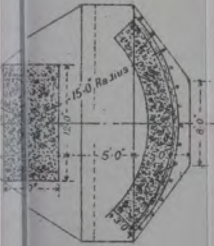
FIG. 7.

FIG. 8.

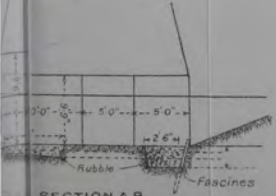


SECTION A.B.

60 PDR MK. I.



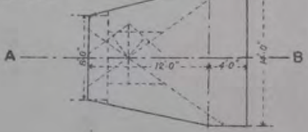
…LAN *(Allows 70° switch)*



SECTION A.B

…HOW. (26 CWTS).

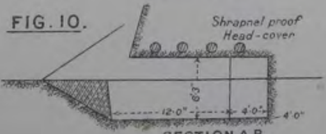
FIG. 9.



PLAN.

Allows 70° switch

FIG. 10.



SECTION A.B.

4·5" HOW.

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SPLINTER-PROOF TRAVERSE.

PROTECTION TO ENTRANCES.

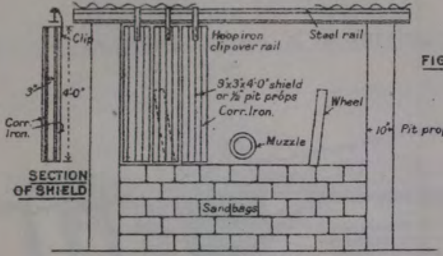


FIG. I.

ELEVATION

PROTECTION TO ENTRANCE.

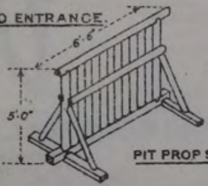
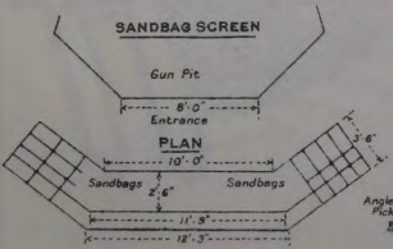


FIG. 3.

PIT PROP SCREEN.

SANDBAG SCREEN



SECTION

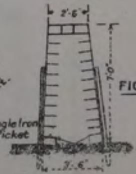


FIG. 2.

Sand bags at right angles to slope.

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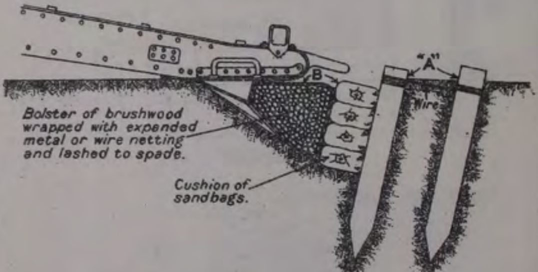
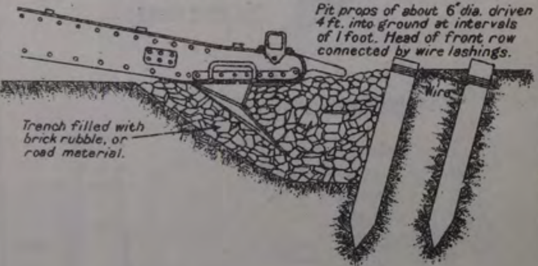
[See Sec. 68, 9.

TRAIL-SUPPORT SHOWING FIXED SUPPORT AT "A" AND CUSHION AT "B".



ALTERNATIVE DESIGN WITHOUT BOLSTER.



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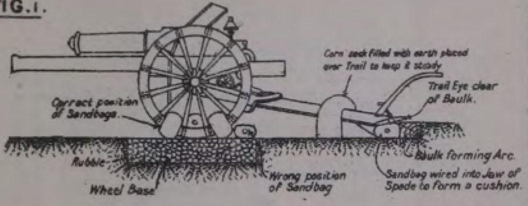
PLATFORM FOR 18-POUNDER.

FIG. 1.



DETAIL OF TRAIL SUPPORT
(ALTERNATIVE)

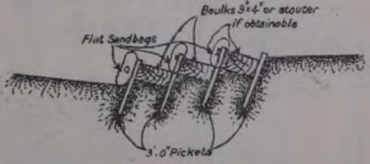


FIG. 2. SECTION.

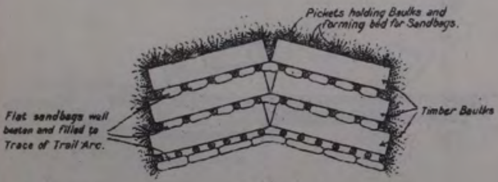


FIG. 3. PLAN.

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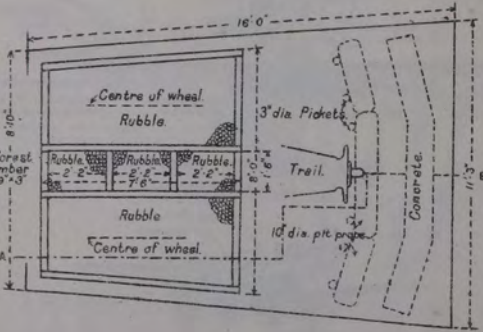
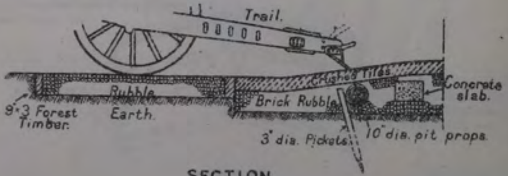
PLATFORM FOR 4·5-INCH HOWITZER.



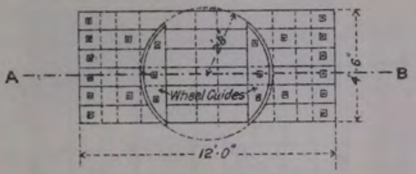
PLAN.

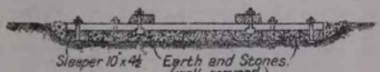


SECTION

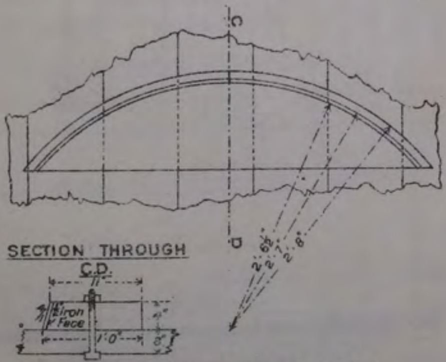
Malby & Sons Lith.

WOODEN WHEEL BED AND WHEEL GUIDES, FOR CARRIAGE, FIELD, B.L. 60-pr. Mk IV.





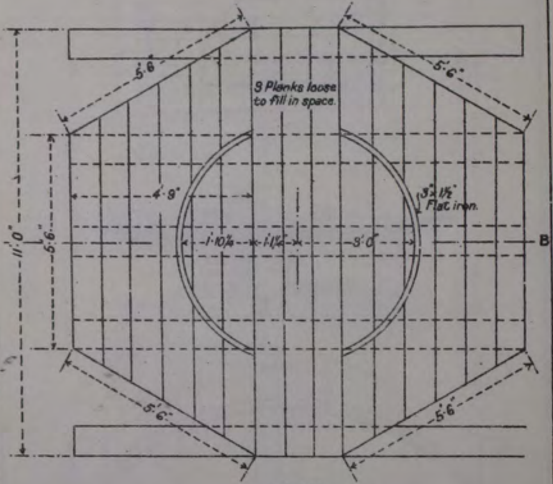
SECTION THROUGH A.B.



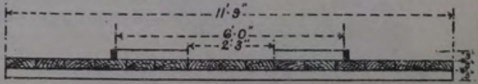
ENLARGED PLAN AND SECTION OF WHEEL GUIDES.

Malby & Sons, Lith.

PLATFORM FOR 6-INCH HOWITZER.



PLAN.



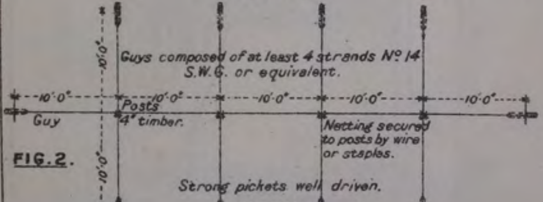
CROSS SECTION
A.B

WIRE NETTING AND CANVAS SCREEN.

FIG. I.

ELEVATION.

FIG. 2.



PLAN.

IMITATION BRICK WALL.

FIG. 3.

FIG. 4.

1702

Malby & Sons, Lith.

SCREENING ROADS.

FIG. 1. PERPENDICULAR TO FRONT.

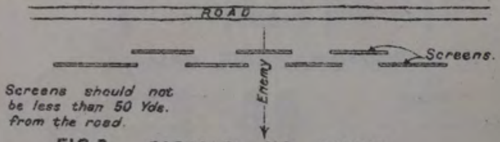


FIG. 2. PARALLEL TO FRONT.

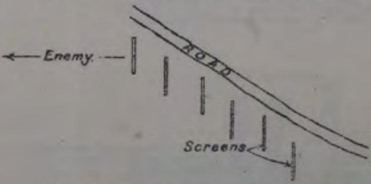


FIG. 3. OBLIQUE TO FRONT.

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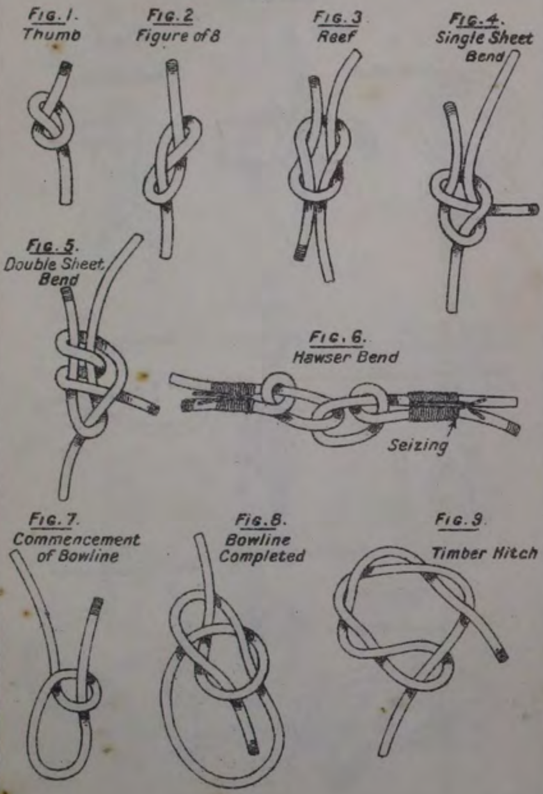
KNOTS.



 Malby & Sons, Lith.

KNOTS.

Fig. 1

Fig. 2

Clove Hitch

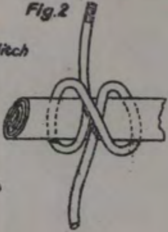


Fig. 3

2 Half Hitches

Fig. 4
Round Turn & 2 Half Hitches

Fig. 5
Fisherman's Bend

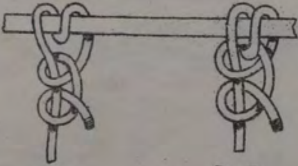


Fig. 6
Running Knot

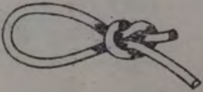


Fig. 7
Bowline on a Bight

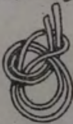


Fig. 8

Lever Hitch

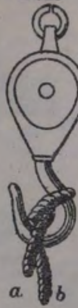
Fig. 9
Man Harness Hitch

KNOTS.

Fig. 1.

Cat's Paw on Centre of Rope

Fig 2.

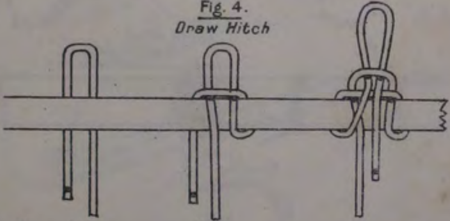


Single Blackwall Hitch

Fig. 3.

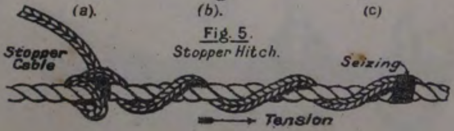
Double Blackwall Hitch

Fig. 4.
Draw Hitch



(a). (b). (c)

Fig. 5.
Stopper Hitch.



Malby & Sons, Lith.

LASHINGS.

FIG. 1.

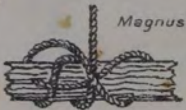


FIG. 2.

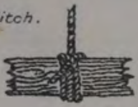


FIG. 3.

FIG. 4.

SQUARE LASHING.

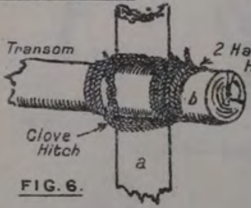
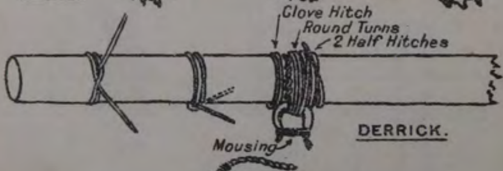


FIG. 5.

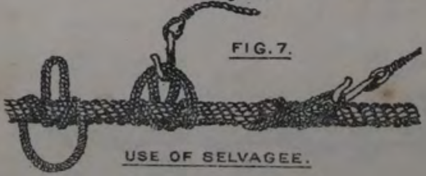
DIAGONAL LASHING.

FIG. 6.



DERRICK.

FIG. 7.



USE OF SELVAGEE.

HOLDFASTS & ANCHORAGES.

FIG. I. 3. 2. I. PICKET HOLDFAST.

FIG. 2. BAULK HOLDFAST.

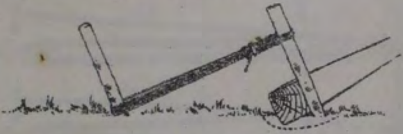
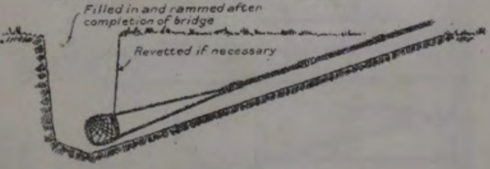
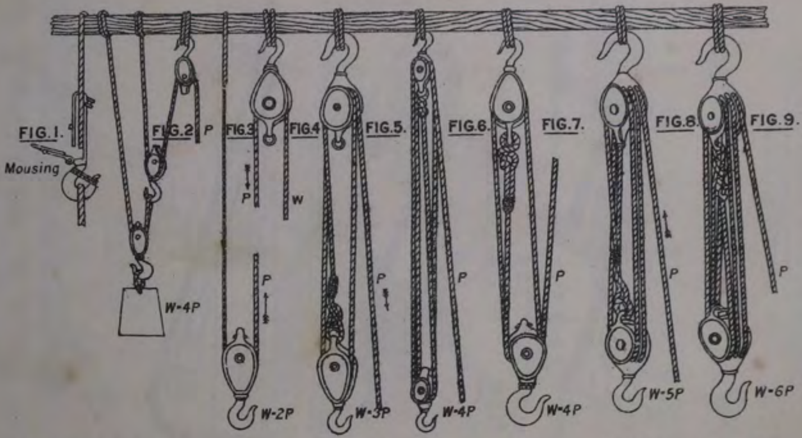


FIG. 3. LOG ANCHORAGE.



TACKLES.



Snatch Block Open — Whip upon whip tackle — Whip — Luff Tackle — Gyn Tackle — Luff Tackle — Light Gyn Tackle — Heavy Gyn Tackle

[See Secs. 77; 78.

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1703.

SWINGING DERRICK.

FIG. I.

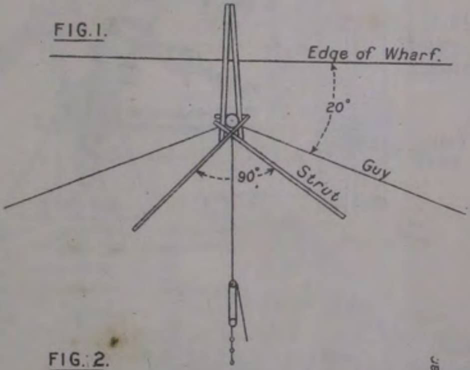


FIG. 2.

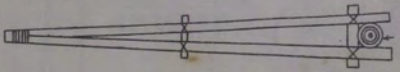
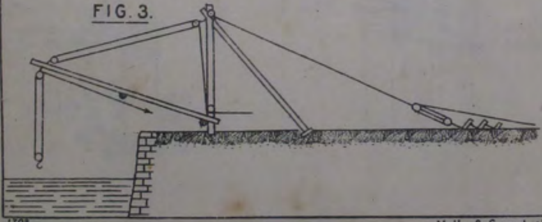


FIG. 3.



1708
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USE OF SPARS.

Fig. 1.
SHEER LASHING.

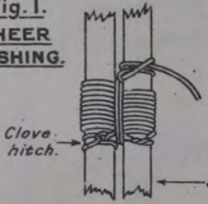


Fig. 2.

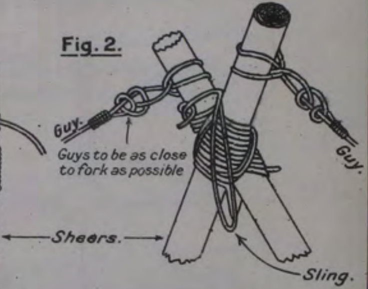


Fig. 3.
GYN LASHING.

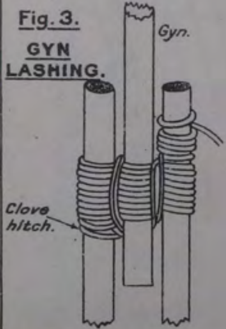
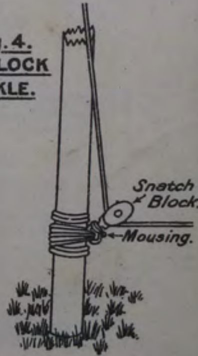


Fig. 4.
LEADING BLOCK FOR TACKLE.



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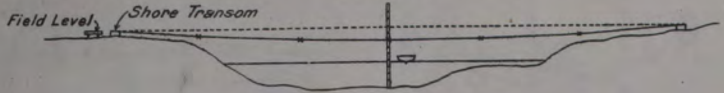
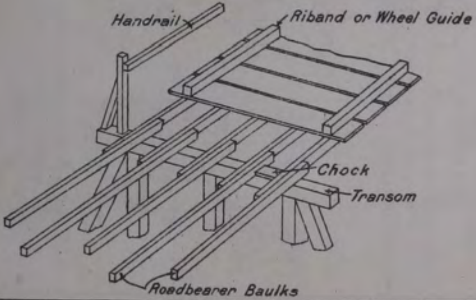
SECTION OF A GAP.

FIG. 1.



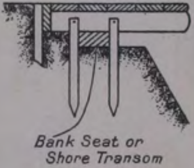
PARTS OF A BRIDGE.

FIG. 2.



SHORE END.

FIG. 3.



See Secs. 86, 3; 87, 3 and 6.

Plate 99.

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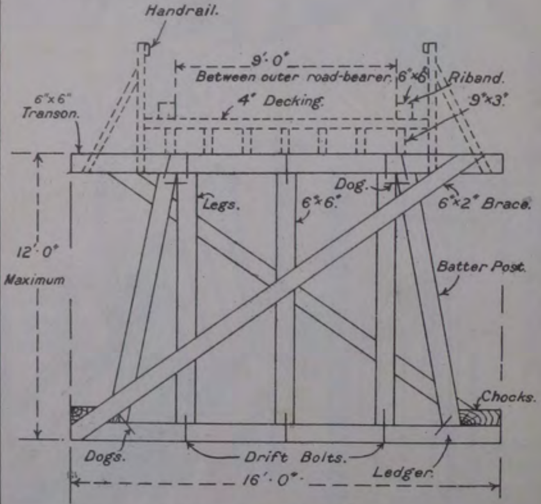
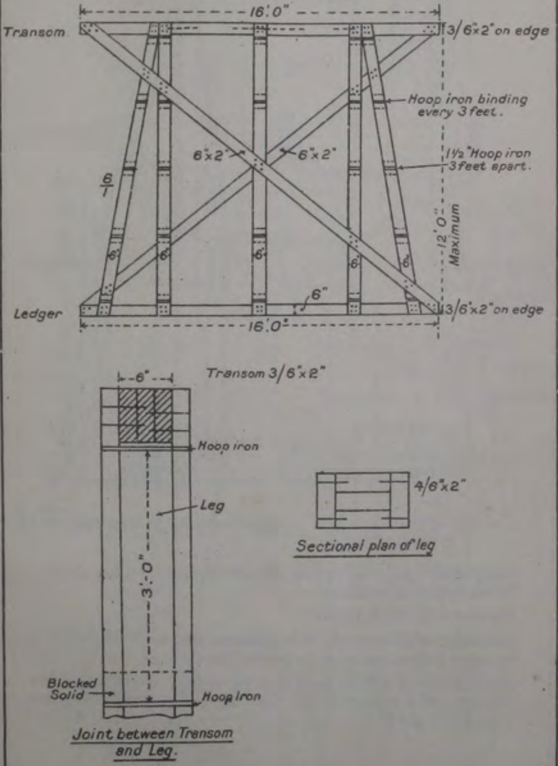
FRAMED TRESTLE.



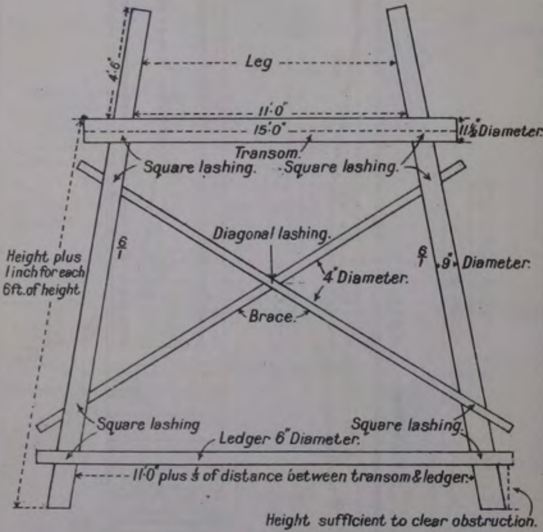
All scantling minimum 6"×6" except braces 6"×2".
For heights 12' to 15' use 4 legs 6"×6" evenly spaced or 3 legs minimum 7"×7".

PLANK TRESTLE.

Out of 6"x2" Timber



LASHED SPAR TRESTLE.



Diameter of spars given are suitable for a 15 foot bay and a 15 feet height of trestle.

For other Spans & Heights:

Transom: 10" diameter for 10 feet bay increase ½ inch diameter for every 2 feet increase in span of bay.

Legs: Reduce ½ inch for every foot decrease in height with 6 inch minimum. With span of 10 feet legs can be ½ an inch lighter than with 15 feet spans.

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See Sec. 88, 2.]

INFANTRY FOOT BRIDGE.

TRUSSED BEAM BRIDGE.

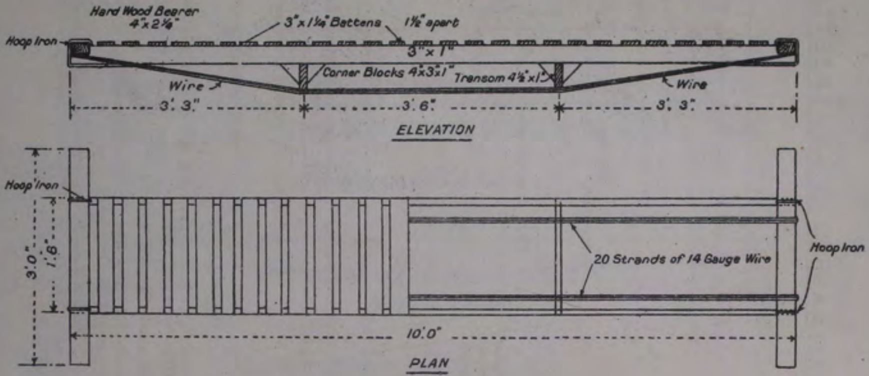

Plate 103.

1703.

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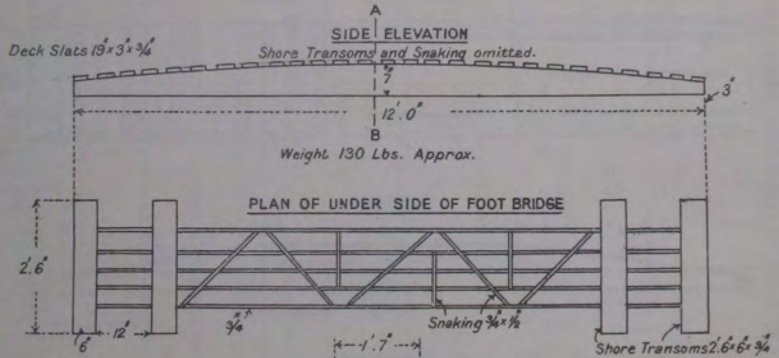
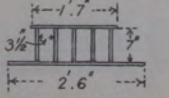
1703.

INFANTRY FOOT-BRIDGE

For Spans up to 11 Feet in the clear.





CROSS SECTION A.B.

Note. For longer Spans than the above Roadbearers should be.

Span in ft 13 – 8"x1"
14 – 8½"x1"
15 – 9"x1"

See Sec. 89, 1.

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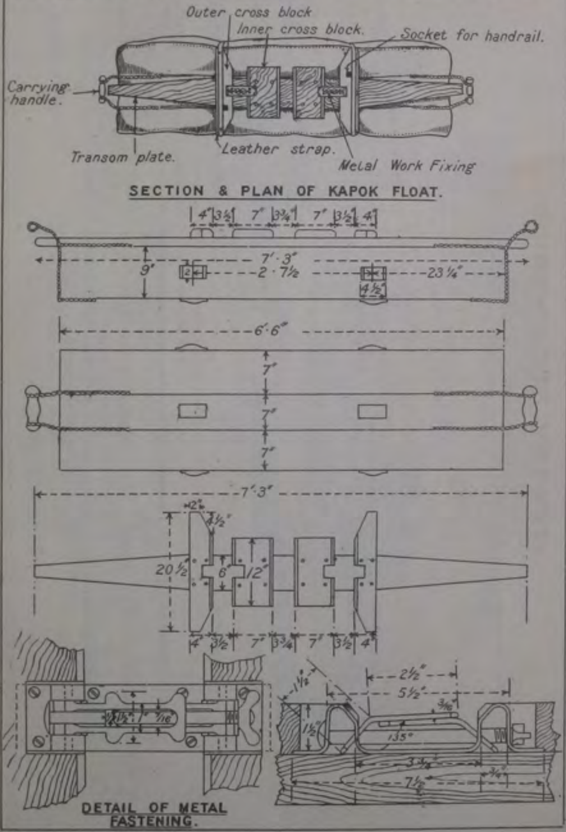
INFANTRY FOOT - BRIDGE.

KAPOK ASSAULT BRIDGE.

FLOATS 8′ APART, CENTRE TO CENTRE, WITH TRENCH-BOARD ROADWAY.

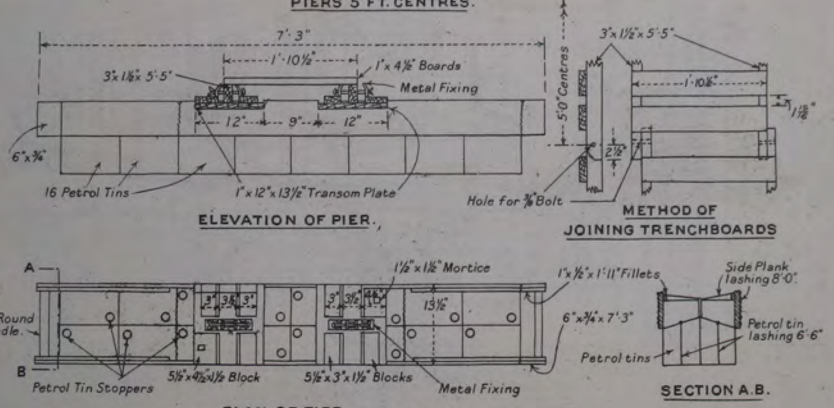


INFANTRY FOOT-BRIDGE.

IMPROVISED ASSAULT BRIDGE.

USING PETROL TINS & STANDARD METAL FASTENINGS.

PIERS 5 FT. CENTRES.



ELEVATION OF PIER.

METHOD OF JOINING TRENCHBOARDS

PLAN OF PIER.

SECTION A.B.

[See Sec. 88, 4.

1793.

INFANTRY FOOT-BRIDGE.

PETROL TIN ASSAULT BRIDGE.

PIERS 8' CENTRE TO CENTRE. WEIGHT OF PIER 110 LBS. WEIGHT OF TRENCH BOARD 48 LBS.

[See Sec. 88, 4.]

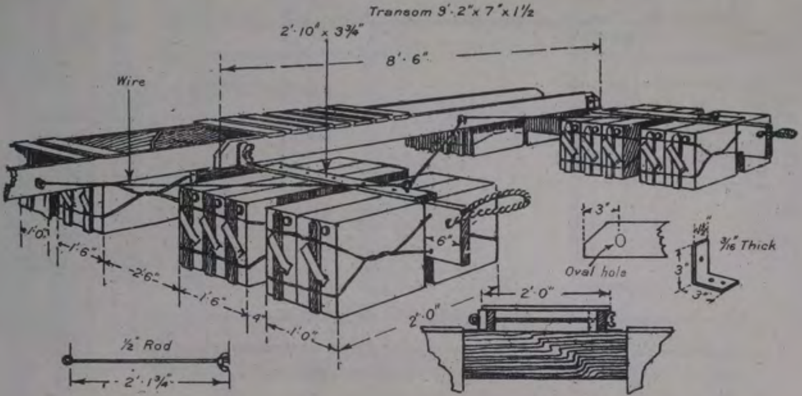


Plate 107.

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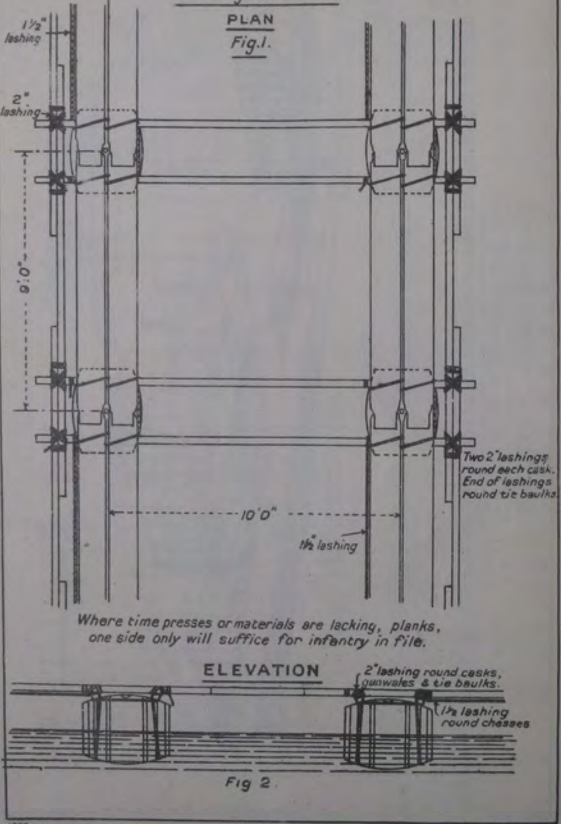
INFANTRY FOOT-BRIDGE.

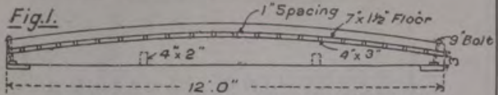
CASK FOOT-BRIDGE.

For 54 gallon casks.



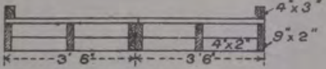
ARTILLERY TRENCH BRIDGE

Fig.1.



SIDE ELEVATION

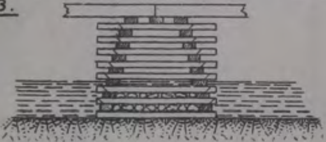
Fig.2.



SECTION

CRIB PIER IN SHALLOW WATER.

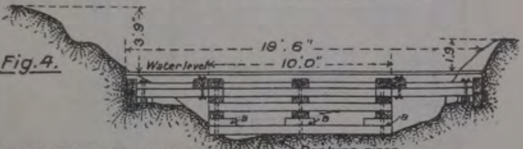
Fig.3.



CRIB CAUSEWAY FOR TANKS.

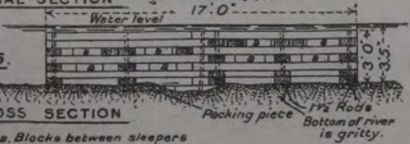
BUILT OF RAILWAY SLEEPERS.

Fig.4.



LONGITUDINAL SECTION

Fig.5.



CROSS SECTION

a.a. Blocks between sleepers

LAUNCHING TRESTLES.

FIG. 1.

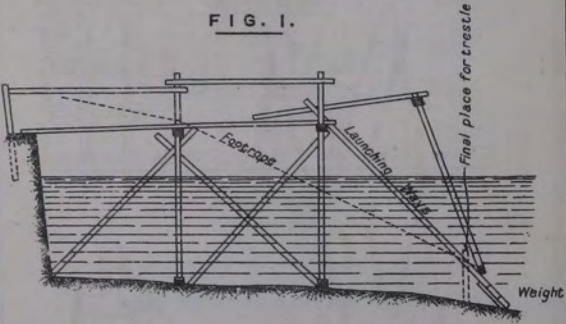
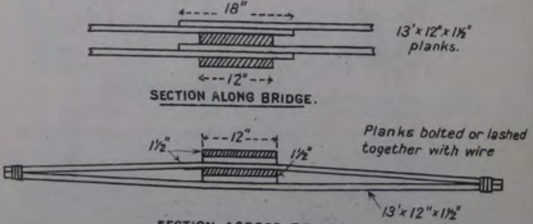


FIG. 2.

PLANK INFANTRY FOOT-BRIDGE.



SECTION ACROSS BRIDGE.

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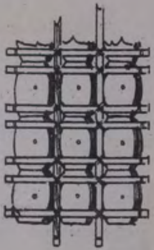
CATAMARAN BRIDGE.

FIG. 1.

SINGLE BARREL RAFT.
FIG. 2.



PIER OF SMALL CASKS.
FIG. 3.

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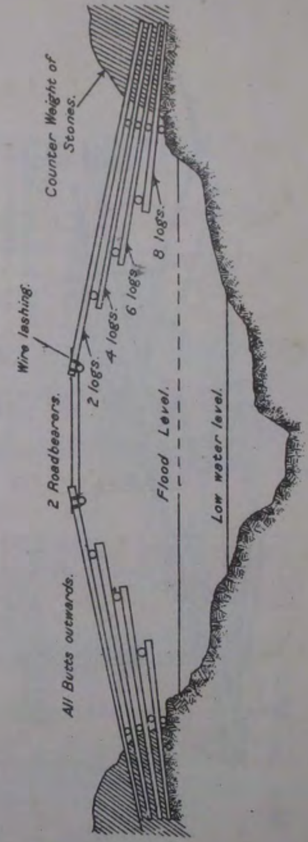
CANTILEVER BRIDGE.



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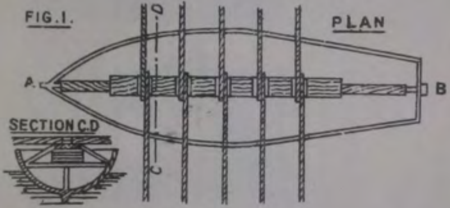
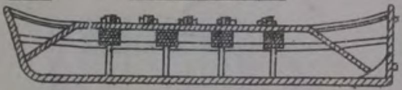
BOAT PIER

FIG. 1. PLAN



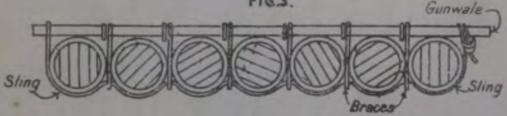
SECTION C.D

FIG. 2. SECTION ON A.B.



BARREL PIER

FIG. 3.



METHOD OF LASHING BARRELS TO GUNWALES.

FIG. 4.

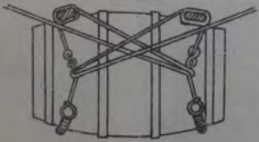
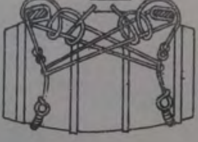


FIG. 5.



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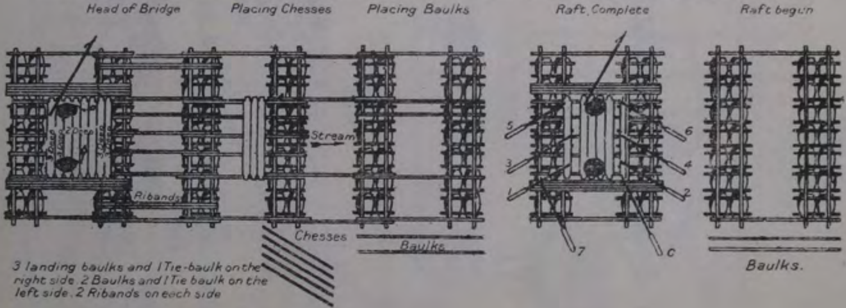
BARREL BRIDGES.

FIG. 1.

FORMING BARREL BRIDGE FOR SWINGING

FIG. 2.

FORMING BARREL RAFTS FOR BRIDGING.



[See Sec. 91, 1.

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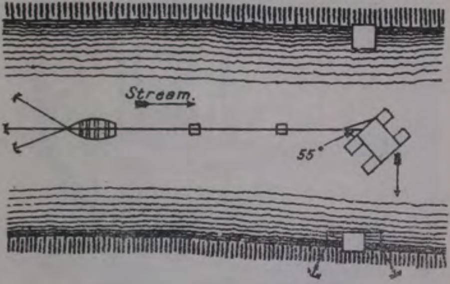
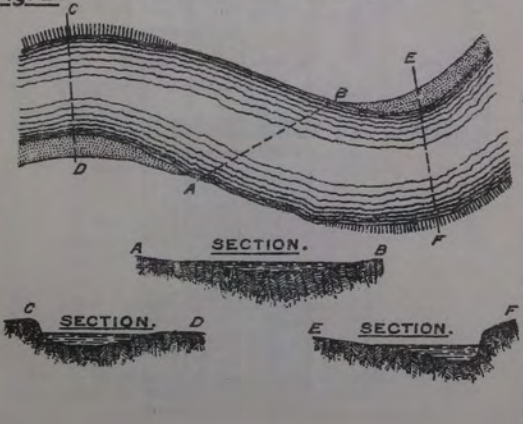
FLYING BRIDGE.

Fig. 1.

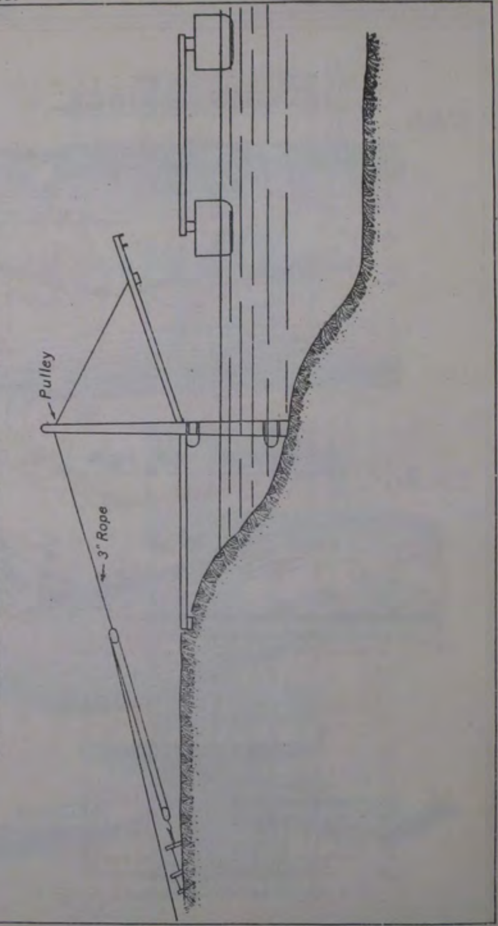


POSITION FOR FORD.

Fig. 2.



LIFTING GANGWAY FOR RAFT APPROACHES.



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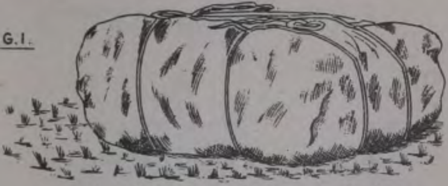
BRIDGING EXPEDIENTS.

Tarpaulin 18'·15' stuffed with straw, &c.

FIG. 1.



Raft of four tarpaulins as Fig. 1.

FIG. 2.

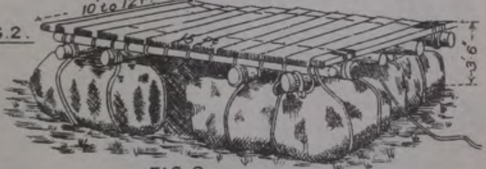
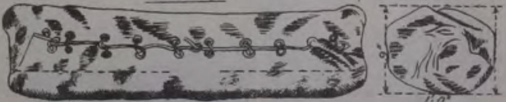


FIG. 3.



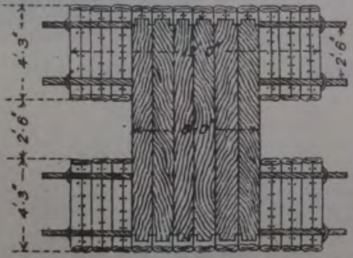


FIG. 4.

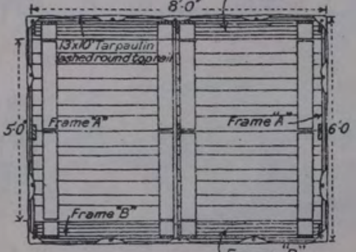
Raft of 24 ground sheets as Fig. 3.

BIVOUAC SHEET BOAT.

Note:-Framing about 5"x¾". Bottom same form as "B" but wider.

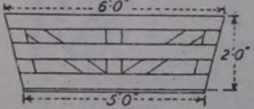
All frames to be lashed together, not nailed 4 Carpenters 2½ hours per raft.

FIG. I.



PLAN

FIG. 2

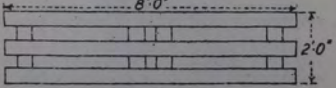


FRAME "A"

FIG. 3.

ELEVATION

FIG. 4.



FRAME "B"

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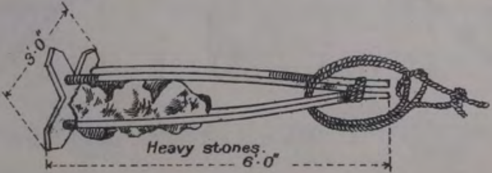
IMPROVISED ANCHORAGES.


Cask with 6 or 8 projecting stakes, & filled with stones.

Head of pick helve rounded, a second pick head driven on to it at right angles to the first & wedged with two spikes.



See Sec. 91, 4.

1709.
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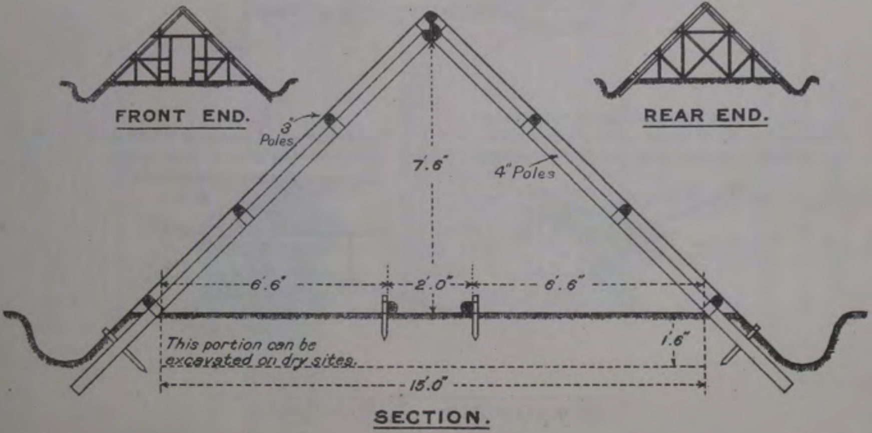
PORTABLE TARPAULIN HUT.



[See Sec. 95, 3.

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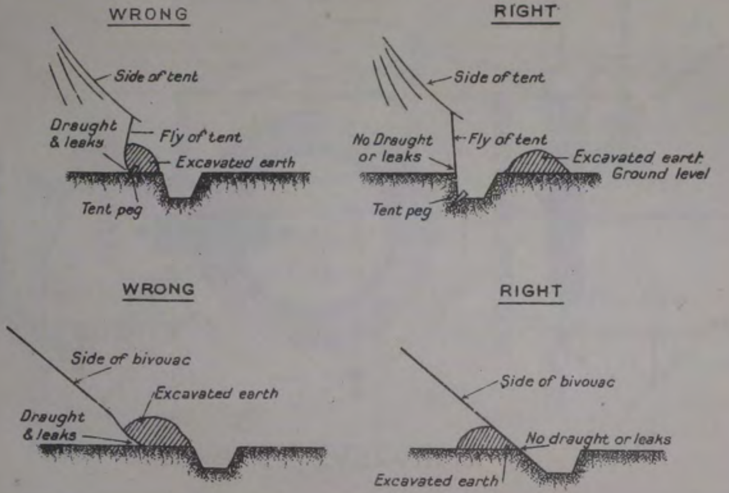
DISPOSAL OF RAINWATER.



See Sec. 95, 4.

Plate 121.

1903.
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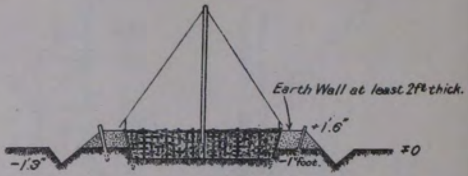
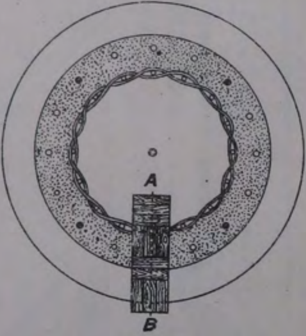
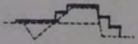
SPLINTER-PROOF PROTECTION FOR TENT.



SECTIONAL ELEVATION.



PLAN.



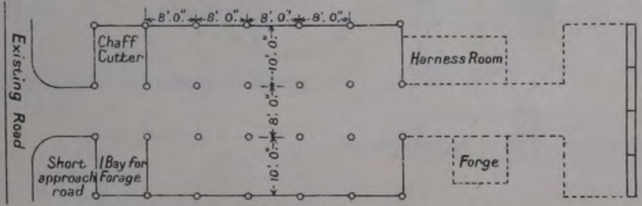
SECTION A-B.

1703.

See Sec. 95, 9.

STABLES.

TYPICAL SECTION.



SITE PLAN.

Plate 123.

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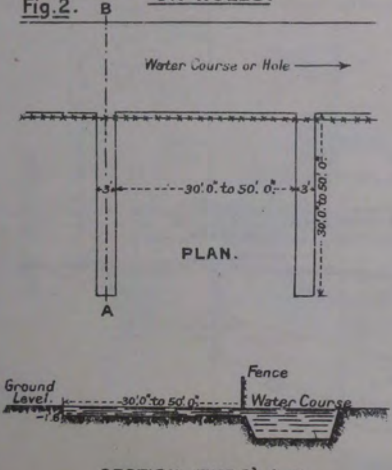
1703.

WATER SUPPLY FROM WATER COURSES OR HOLES.

Fig. 2.

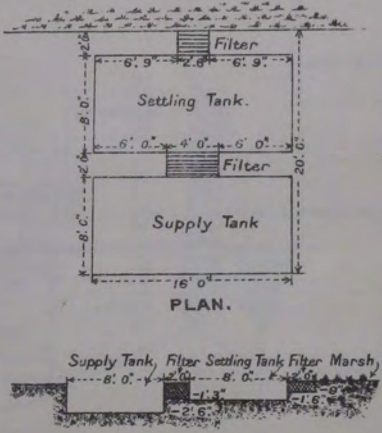


PLAN.

SECTION THRO' A-B.

WATER SUPPLY FROM MARSH.

Fig. 1.



PLAN.

SECTION.

[See Sec. 96, 3 and 10.

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See Sec. 96, 7.

WATER BAG.

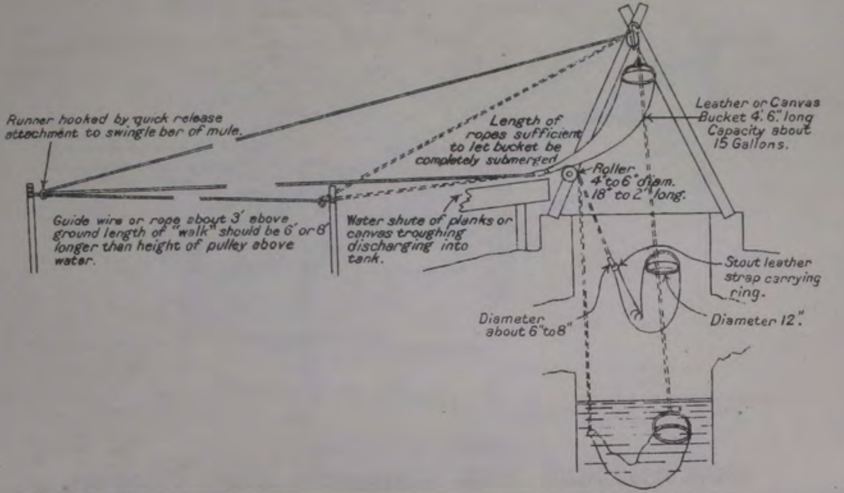

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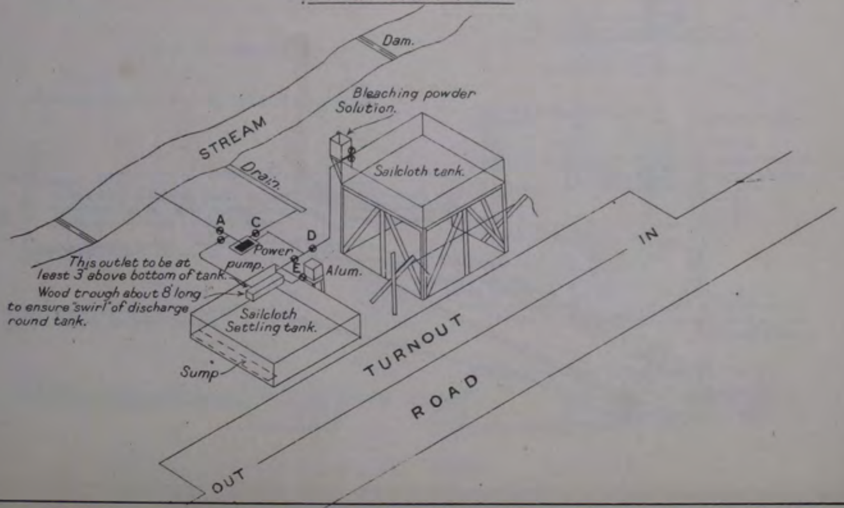
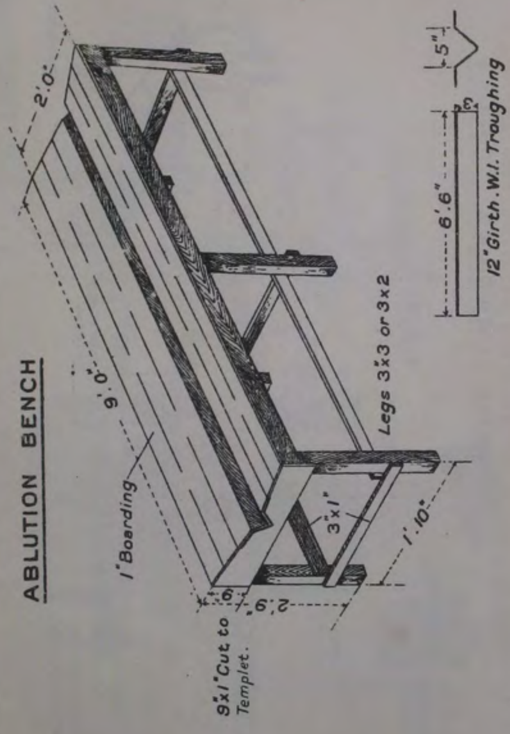
Plate 125.

Plate 126.

IMPROVISED WATER PURIFICATION PLANT COMBINED WITH WATER CART POINT.

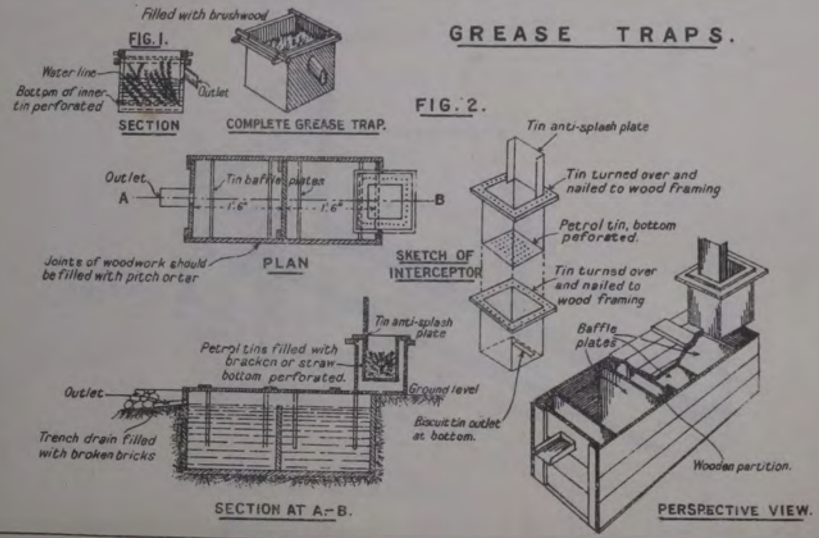


[See Sec. 96, 6.



ABLUTION BENCH

GREASE TRAPS.



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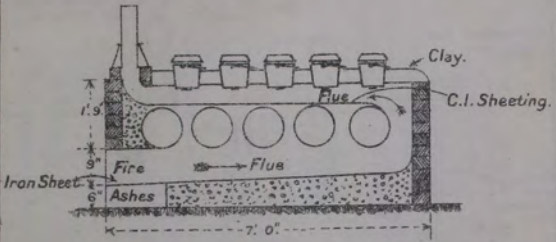
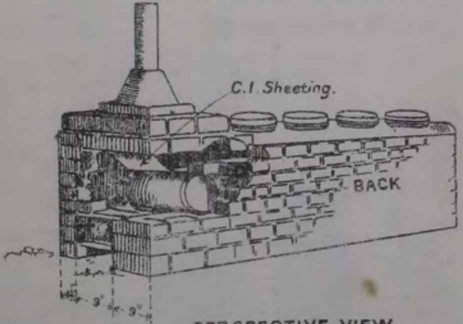
OIL DRUM OVEN.



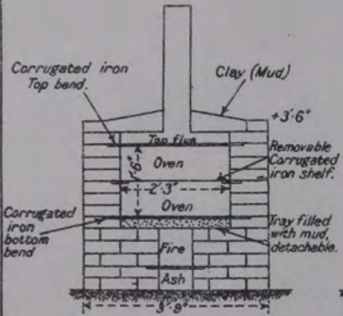
SECTION.



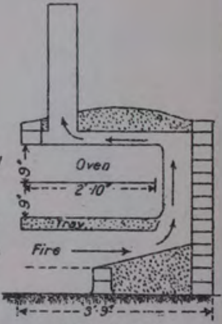
PERSPECTIVE VIEW.
Showing method of fixing Oil Drums.

Malby & Sons Lith

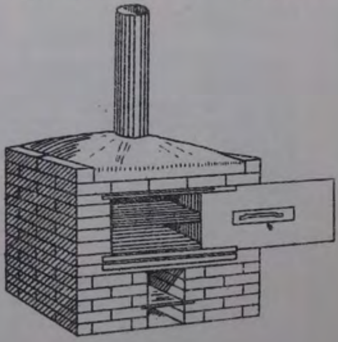
CHAMBER OVEN.



SECTION THROUGH CHIMNEY.



SIDE VIEW.



PERSPECTIVE VIEW.

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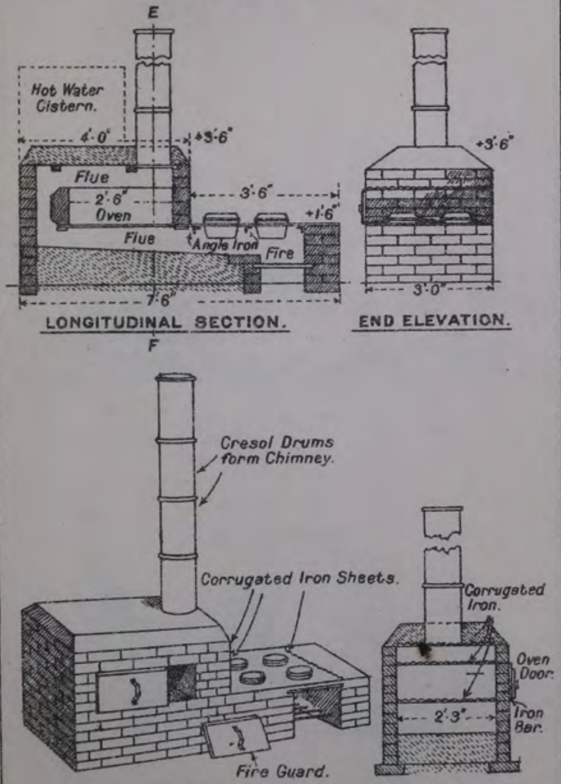
COOKER FOR CAMPS AND BILLETS.



LONGITUDINAL SECTION.

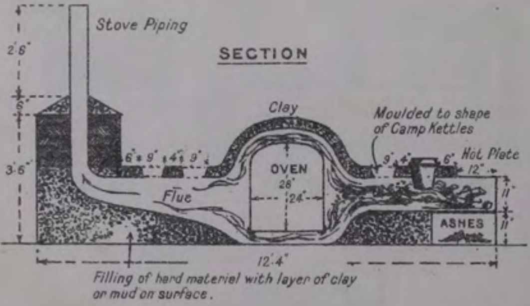
END ELEVATION.

PERSPECTIVE VIEW.

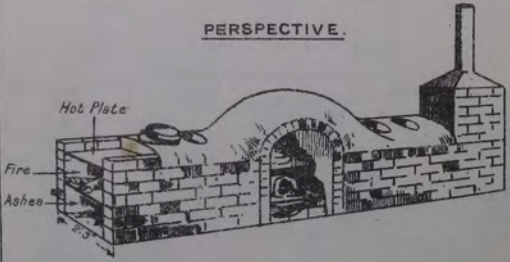
SECTION E.F.

CAMEL BACK OVEN.

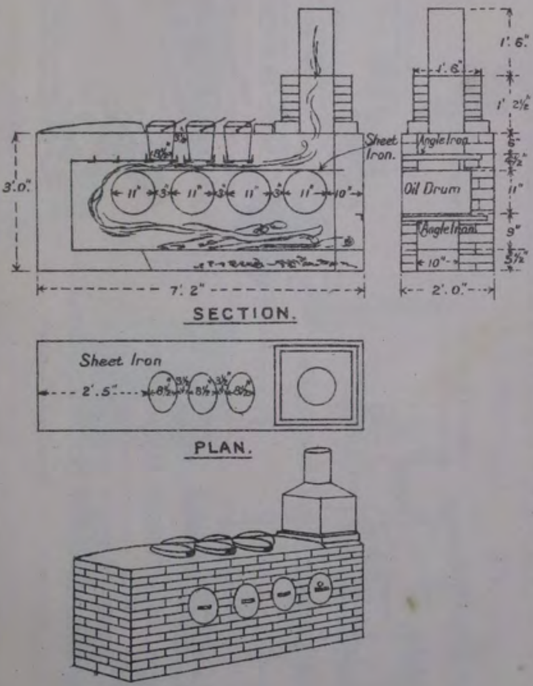
SECTION



PERSPECTIVE.



CAMP COOKER



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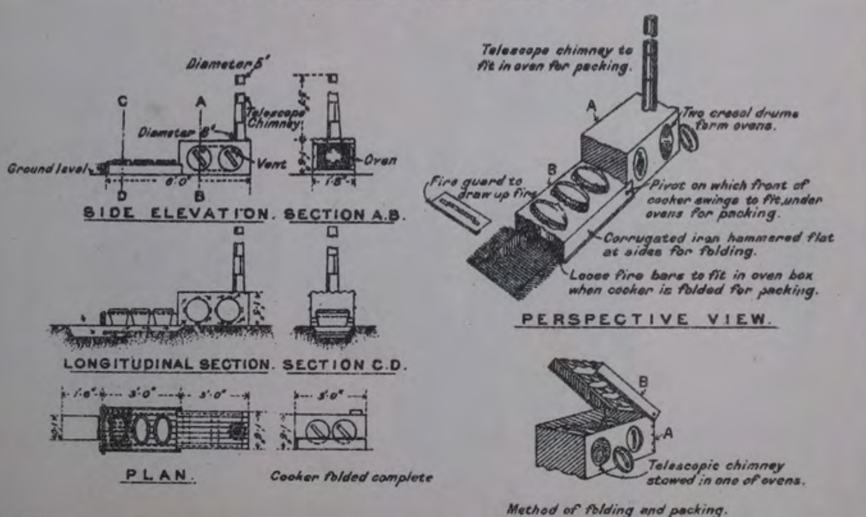
[See Sec. 97, 3.

PORTABLE FIELD KITCHEN.



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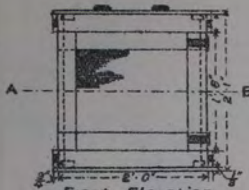
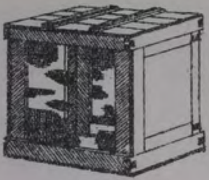
See Sec. 97, 5.

PORTABLE FLY PROOF MEAT SAFE.

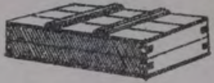
All Framing made from 3" x 3/4" Timber.



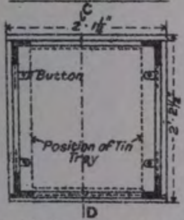
Front Elevation.



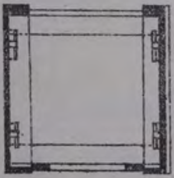
Perspective View.



Meat Safe Closed.

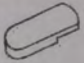


Plan of Section at A.B.



Elevation of Section C.D.

Detail of Joint for Framing.



Detail of Button.

Detail of Joint. for Trays.

Plate 135.

1709

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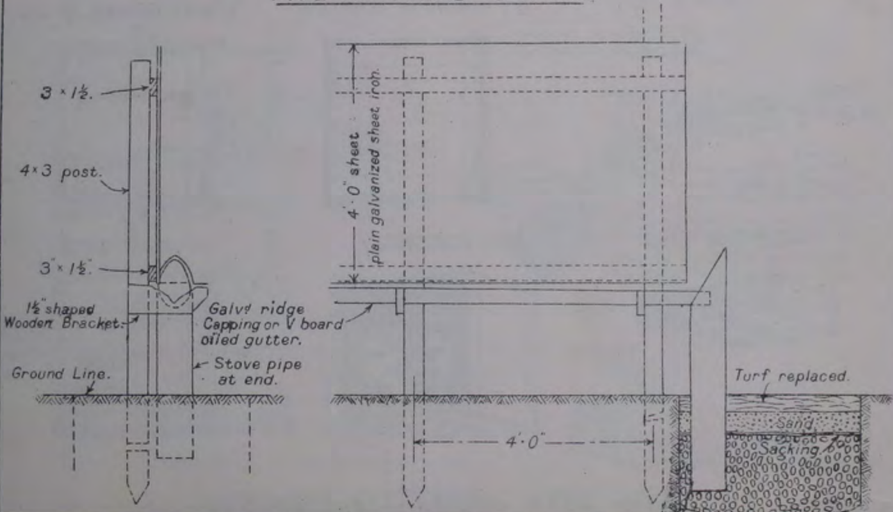
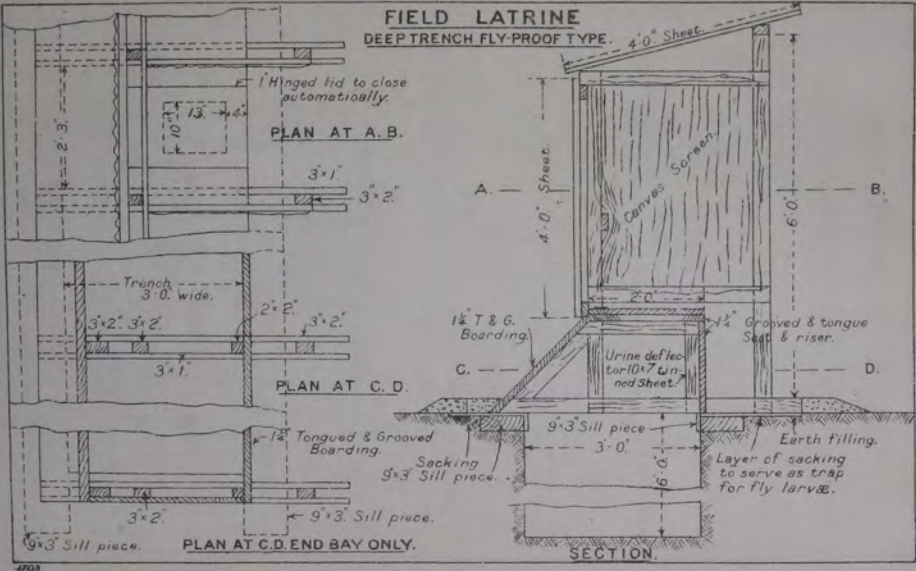
[See Sec. 98, 2.

TYPE OF FIELD URINAL.

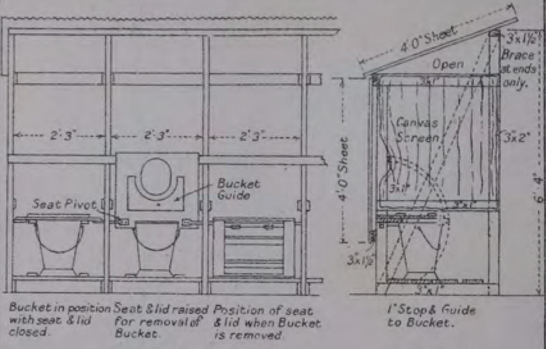




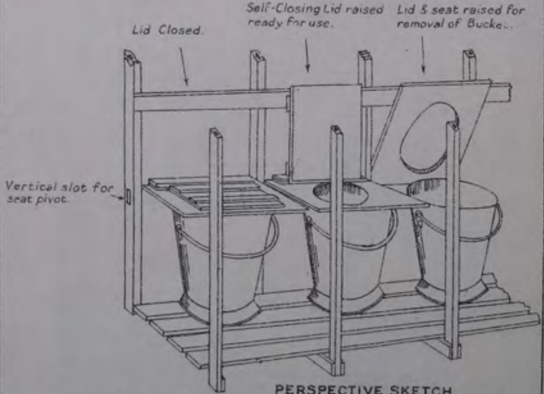
[See Sec. 98, 2.]

Plate 137.

FIELD LATRINE. BUCKET TYPE.



ELEVATION. SECTION.



PERSPECTIVE SKETCH.

Note:- The guides & stops to Buckets should be so arranged that the seats & lids fit accurately over the Buckets and should be fly-proof.

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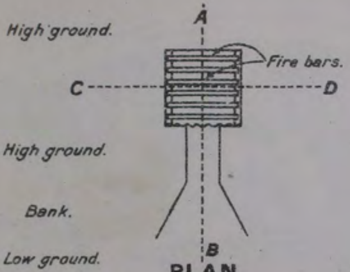
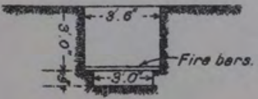
TEMPORARY INCINERATOR.

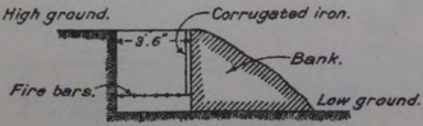


PLAN.

Incinerator dug out of side of bank.
Refuse fed at top of incinerator from high ground and drawn from passage cut out of bank side.

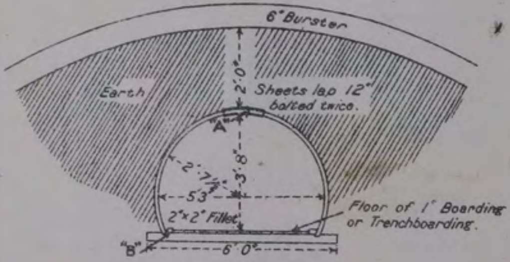


SECTION C-D.

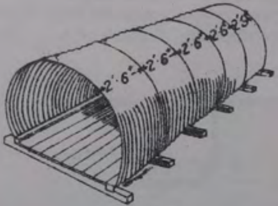


SECTION A-B.

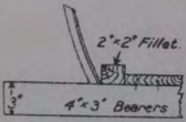
SMALL CORRUGATED STEEL SHELTER.



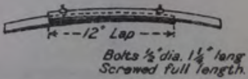
SECTION



PERSPECTIVE.



DETAIL AT "B"



DETAIL AT "A"

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SPLINTER-PROOF SHELTER.

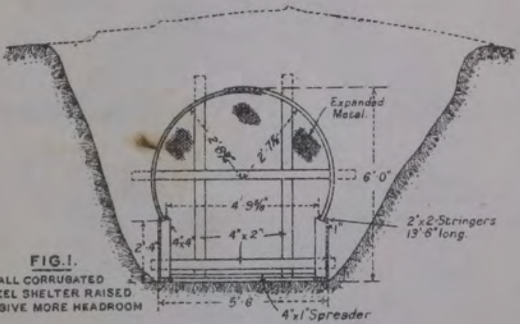


FIG. I.
SMALL CORRUGATED STEEL SHELTER RAISED TO GIVE MORE HEADROOM

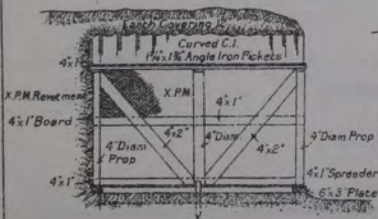
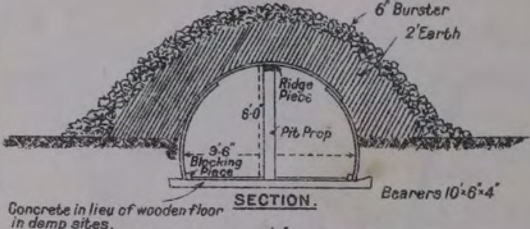


FIG. 2.
SECTION.

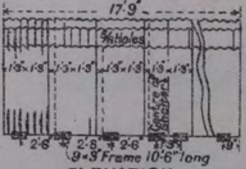
FIG. 3.
FRONT ELEVATION

USING SHEETS OF CURVED C.I.

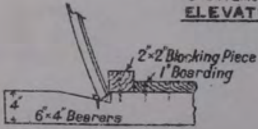
LARGE CORRUGATED STEEL SHELTER.



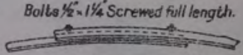
SECTION.



ELEVATION.



DETAIL OF "B"



DETAIL OF LAP "A"

Material required for each Shelter 17'·9" long
21 Sheets of large corrugated Shelter (Each 2'·9" wide 3" inch lap)
60 Bolts
8 Bearers 10'×6"×4". 4 Pit Props
160 Sq. Ft. of Boarding for floor
Gas-proof double door frame complete
Accommodation double bunked 12 men in each shelter.

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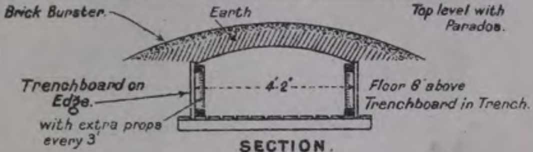
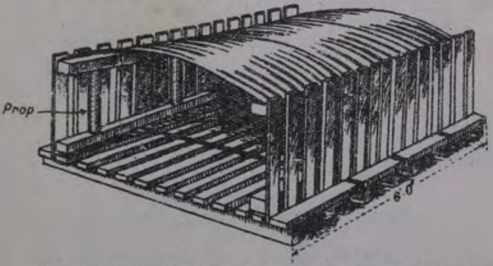
SHRAPNEL-PROOF SHELTERS.

INFANTRY TRENCH SHELTER BEHIND PARADOS.

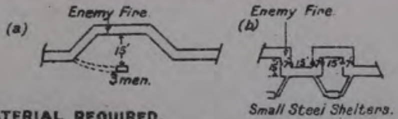


SECTION.

SKELETON SKETCH SHOWING CONSTRUCTION.



SKETCH SHOWING POSITION OF ENTRANCE ON SAFE SIDE.



MATERIAL REQUIRED.

3. Curved sheets of small corrugated steel shelter.
2. Trenchboards for sides.
4. Trenchboards for floor.
2. Old corrugated sheets or boarding to form back.
Brick rubble for top cover.
Accommodation – 2 to 3 men.

NOTE:– Level of bottom of fire trench will regulate level of bottom of shelter, i.e. there will be a gradual down grade from bottom of shelter to bottom of fire trench for drainage.

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TIMBER CONSTRUCTION.

COMMON FAULTS.

FIG. 1.

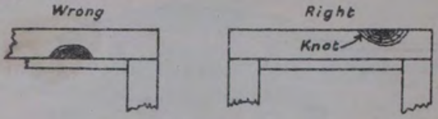


FIG. 2.

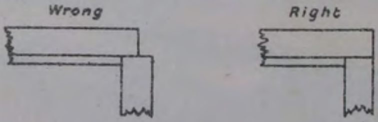


FIG. 3.

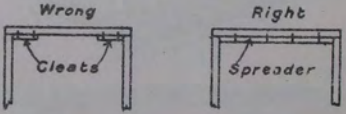
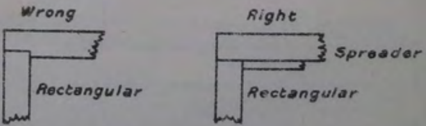


FIG. 4.



TIMBER CONSTRUCTION
COMMON FAULTS

Fig. 1.

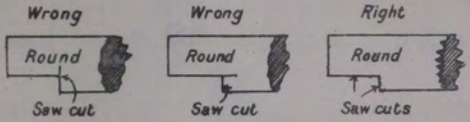


Fig. 2.

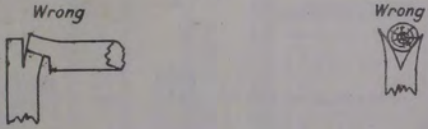
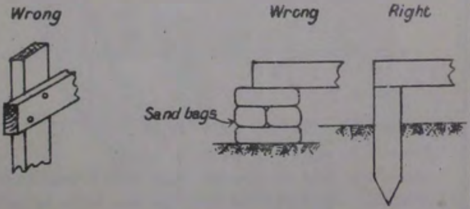


Fig. 3.



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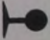
STRENGTH OF BEAMS

CALCULATION OF LOAD.

Fig. I.

Rails must be laid thus  *not* 

Steel joists must be laid thus  *not* 

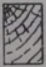
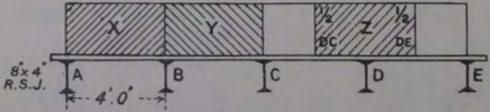
Timber joists must be laid thus  *not* 

Fig. 2



Beam "B" supports half "X" and half "Y".
Beam "A" supports half "X" only
Therefore in a continuous roof with a load evenly distributed, estimate the load on any beam by taking the cubic contents over half the distance betwee that beam and those on each side of it, as at "Z"

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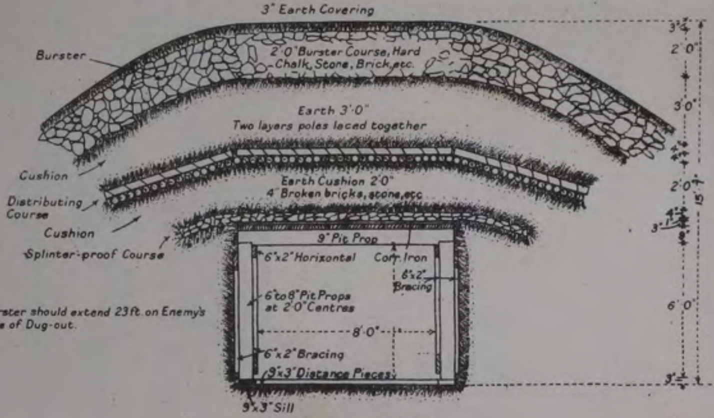
See Sec. 105, 7; Appendix VIII Table 6.

SPECIMEN OF SUITABLE COVER.

PROOF AGAINST SHELLS UP TO 6-INCH.



Note:-
Burster should extend 23 ft. on Enemy's side of Dug-out.

CROSS SECTION:

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STANDARD SETTS & CLIPS
3" TIMBER.

FIG. 1.

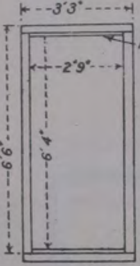
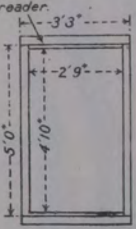
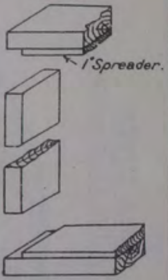


FIG. 2.



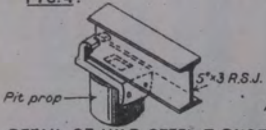
ELEVATIONS.

FIG. 3.



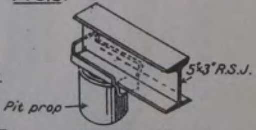
STANDARD JOINTS.

FIG. 4.



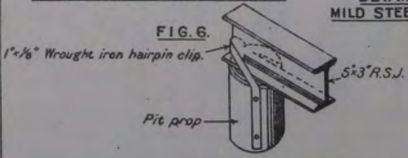
DETAIL OF MILD STEEL Z SHOE.

FIG. 5.



DETAIL OF
MILD STEEL SHOE Mk II.

FIG. 6.



DETAIL OF HAIRPIN CLIP.

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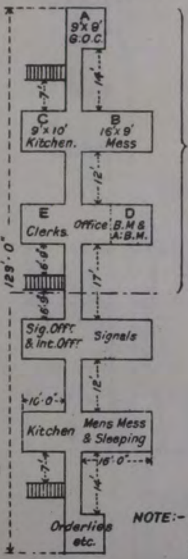
STANDARD DUG-OUT ACCOMMODATION FOR HEADQUARTERS.

BRIGADE HEAD QRS



FOR BATTN BATTLE H.Q.
(Double Bn. H.Q. = One Bde H.Q.)

C.O. Room	A
Mess & Office	B
Kitchen	C
Adjt. & Clerks	E
Men & Orderlies	D

FOR H.A. BATTY H.Q.

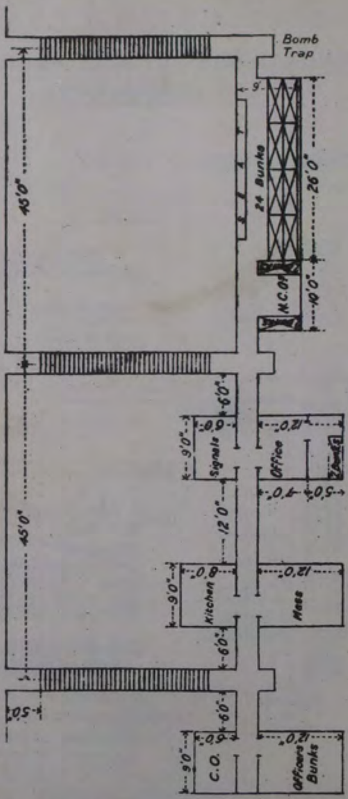
B.C. Post	A
Wireless	E
Officers Bunks, Mess	B & C
Men 60 O.R. For 2 Guns.	

FOR ARTY BDE. H.Q.
Same as for BATTN

NOTE:- Wherever possible Bn H.Qrs should be arranged in pairs on the above lines, so as to be available as Bde H.Qrs in an advance.

BATTALION BATTLE HEADQUARTERS.

WITH ACCOMMODATION FOR 28 MEN.



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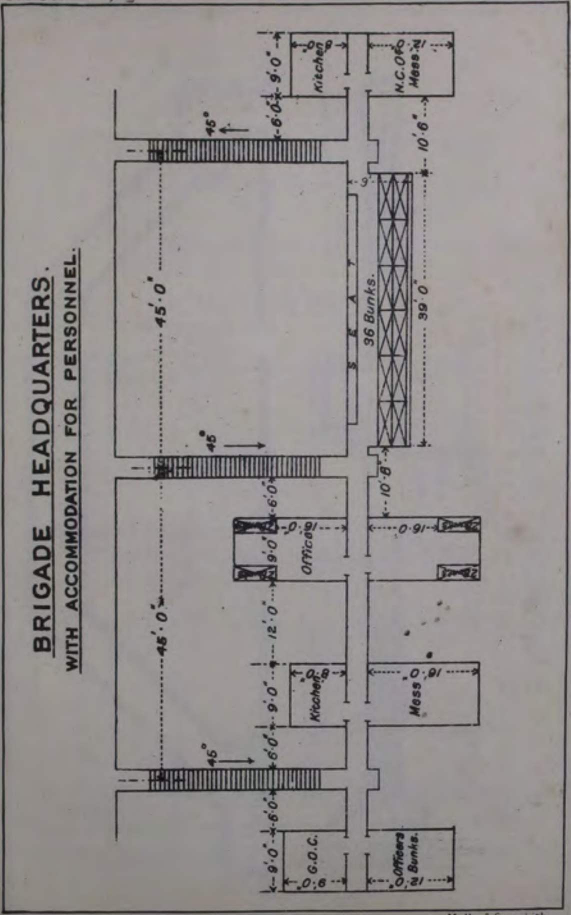

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M.G. DUG-OUT & EMPLACEMENT.

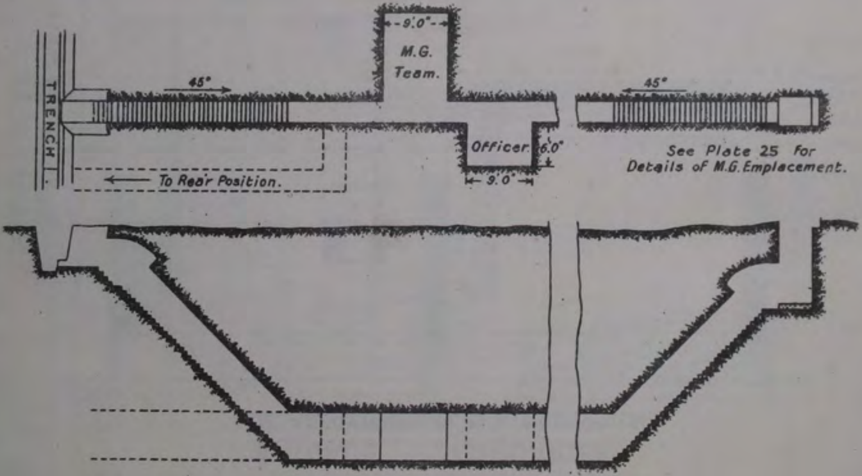

Plate 152.

[See Sec. 106, 5

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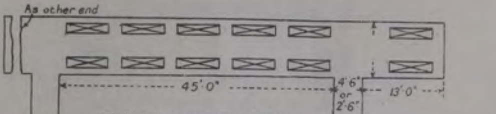
DRESSING STATION.



GENERAL ARRANGEMENT.

FIG. 1.

DETAIL OF BRACKETS.

FIG. 2.

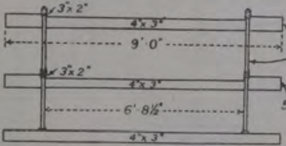
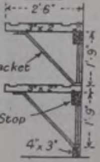


FIG. 3.



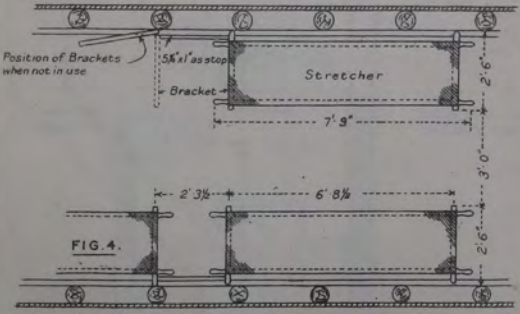


FIG. 4.

PLAN SHOWING ARRANGEMENT OF BRACKETS & STRETCHERS.

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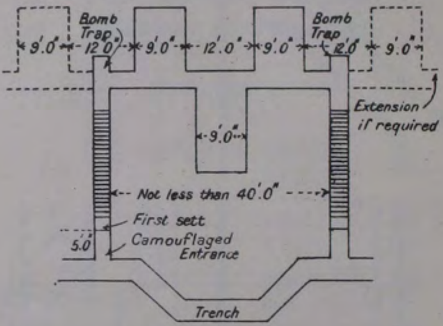
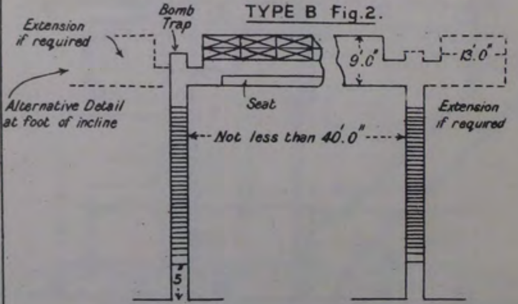
TYPES OF DUG-OUTS

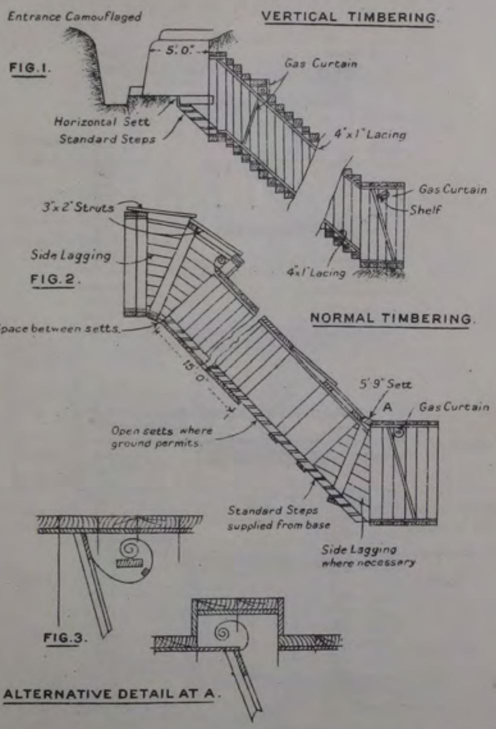
TYPE A Fig. 1.



TYPE B Fig. 2.

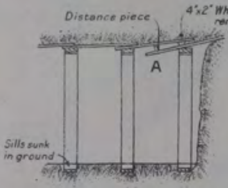


ENTRANCES AND INCLINES.

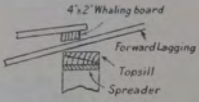


See Sec. 106, 10 and 12.

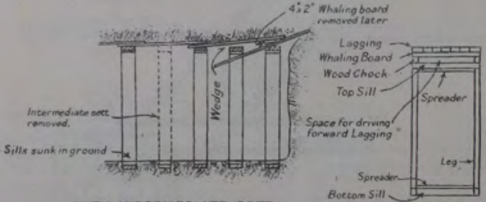
SPILING.



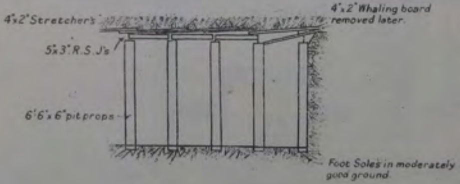
WITHOUT INTERMEDIATE SETT.



DETAIL AT A



WITH INTERMEDIATE SETT.



WITH PIT PROPS AND R.S.Js.

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GAS-PROOF CURTAINS.

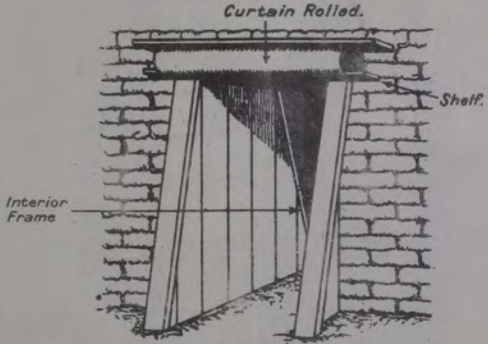


FIG. I. Open.

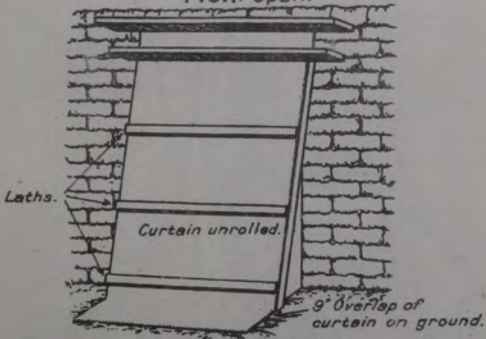


FIG. 2. Closed.

GAS-PROOF CURTAINS.

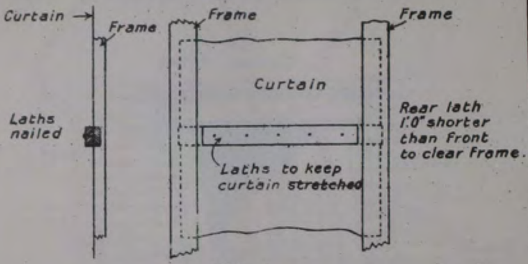


FIG. I.

DETAILS OF LATHS KEEPING CURTAIN STRETCHED.

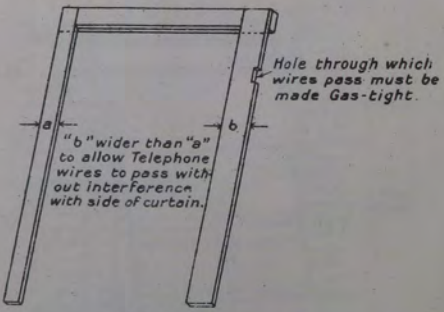
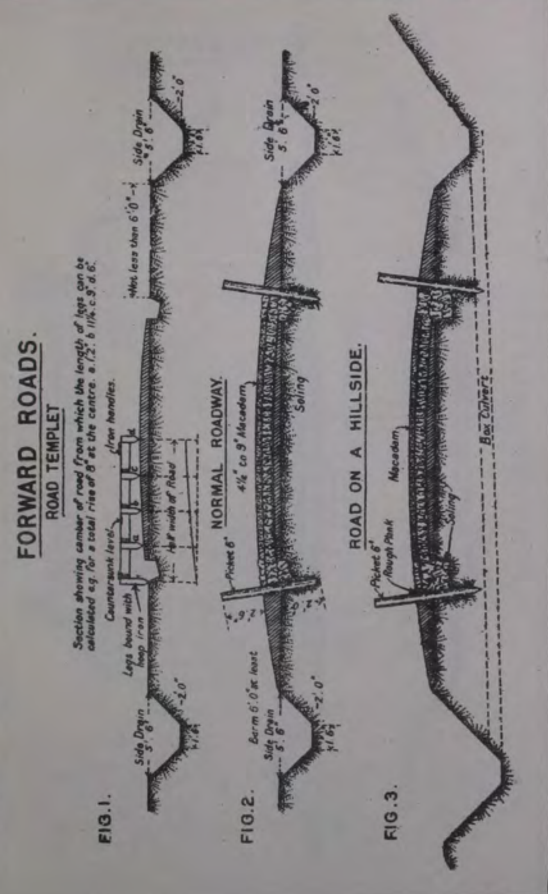


FIG. 2.

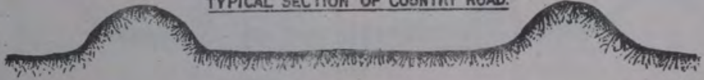
PERSPECTIVE OF FRAME WHEN TELEPHONE WIRES PASS ALONG GALLERY.


FORWARD ROADS.
ROAD TEMPLET
Section showing camber of road from which the length of legs can be calculated e.g. for a total rise of 8" at the centre. a. 1/2". b 1 1/4". c. 9". d. 6".
FIG.1.
Side Drain 5'.6"
2'.0"
1'.6"
Legs bound with hoop iron
Countersunk level
Iron handles
Half width of Road
Not less than 6'.0"
NORMAL ROADWAY.
FIG.2.
4½" to 9" Macadam
Soling
Picket 6'
Berm 6'.0" at least
Side Drain 5'.6"
ROAD ON A HILLSIDE.
FIG.3.
Picket 6'
Rough Plank
Macadam
Soling
Box Culvert

FORWARD ROADS.

TYPICAL SECTION OF COUNTRY ROAD.

FIG. 1.



COUNTRY ROAD REMADE

FIG. 2.

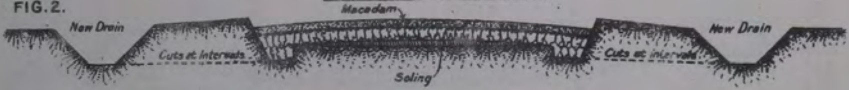
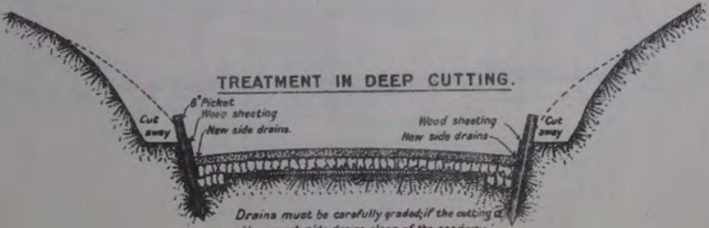


FIG. 3.

TREATMENT IN DEEP CUTTING.



[See Sec. 109, 5

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FORWARD ROADS.

METHOD OF WIDENING PAVE ROAD.

FIG. 1.

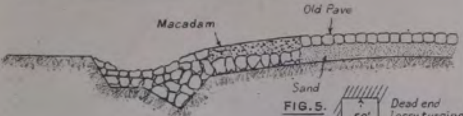


FIG. 5.

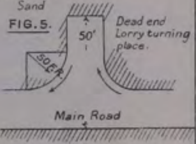
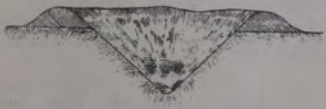


FIG. 2. SHELL HOLES.

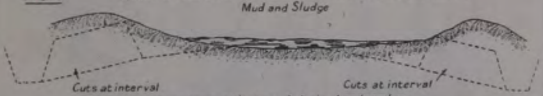


Cut the shell-hole square ramming the bottom of the hole

Then fill shell-hole with sandbags laid properly, on the top of the sandbags the roadway is now made in the usual way. If the shell-hole has water in it it must be pumped dry before it is filled.

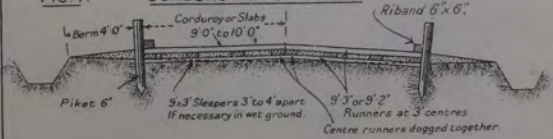
ROAD REPAIR.

FIG. 3. Section of road to be repaired. Foundations completely disappeared.



Dotted line shows how road is cleared, drained and camber cut for new foundation.

FIG. 4. CORDUROY OR SLAB ROAD.



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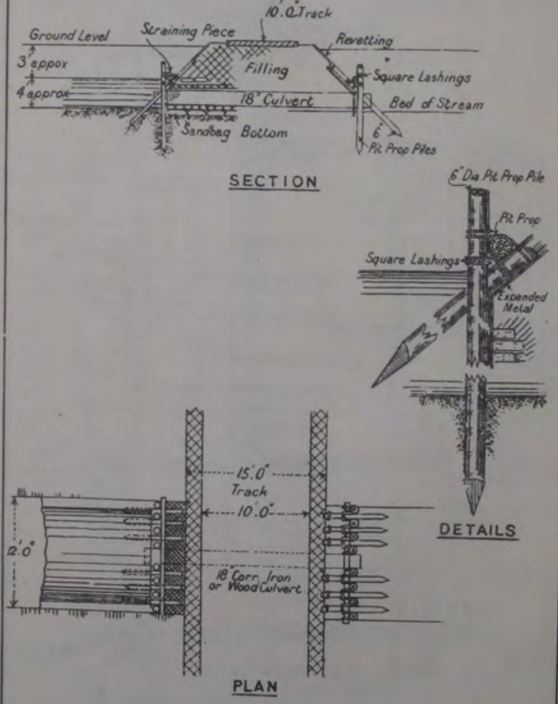
TANK CAUSEWAY



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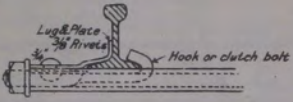
9-LB TRACK.

Fig. 1.



Figs. 2 and 3 Section detail of Section Crossing.

Fig. 2.

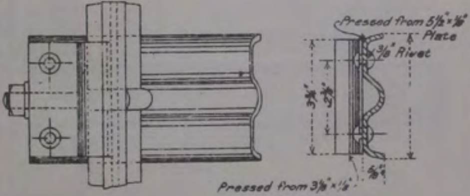
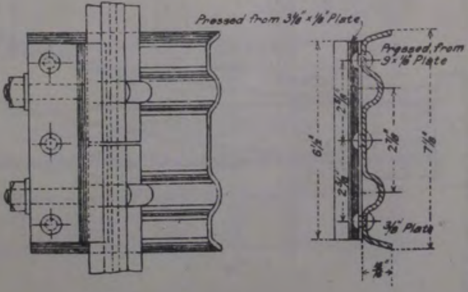


Fig. 3.

Joint Plate



9-LB. TRACK.

FIG. 1.
5M STRAIGHT SECTION.
Length of rails 5m (16'·4⅞")

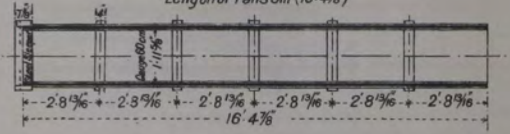


FIG. 2.
2·5 M STRAIGHT SECTION.

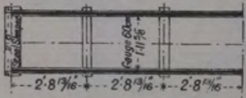


FIG. 3.
2·5M CURVED SECTION (8'·2 7/16")

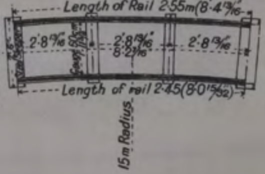
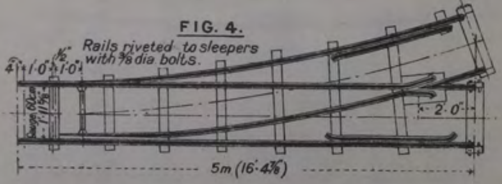


FIG. 4.



20-lb. TRACK.

FIG. 1. 5м. STRAIGHT SECTION (TYPE A)

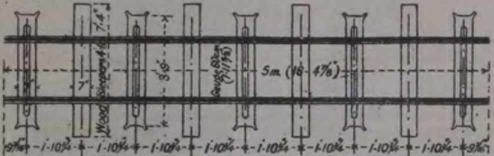


FIG. 2. 2·5м. STRAIGHT SECTION (TYPE A).

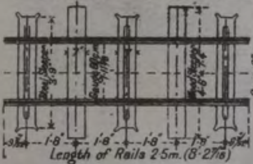


FIG. 3. 2·5м. CURVED SECTION (TYPE A)

30 m. Radius.

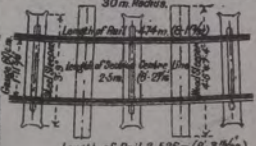


FIG. 4. 5м. CURVED SECTION (TYPE A).

30m. Radius.

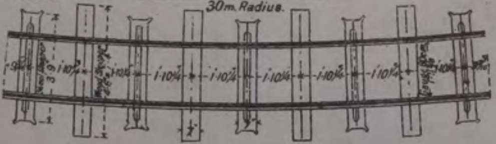
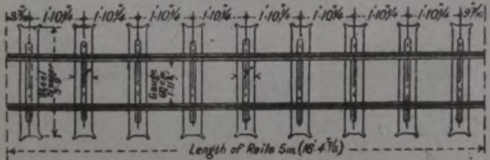


FIG. 5. 5м. STRAIGHT SECTION (TYPE B).



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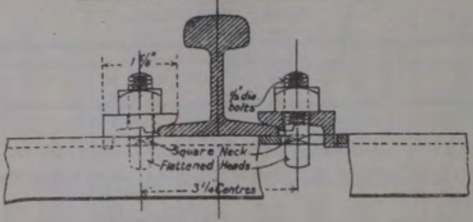
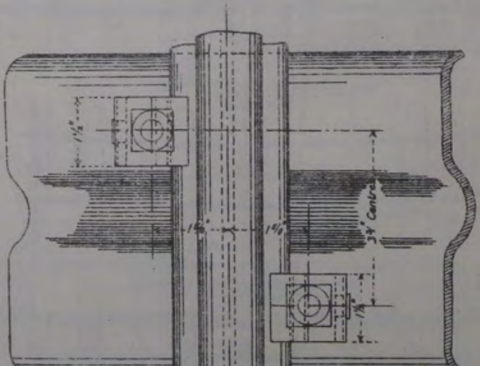
[See Sec. III, 4.

20-LB TRACK.

LONGITUDINAL SECTION THROUGH SLEEPER.





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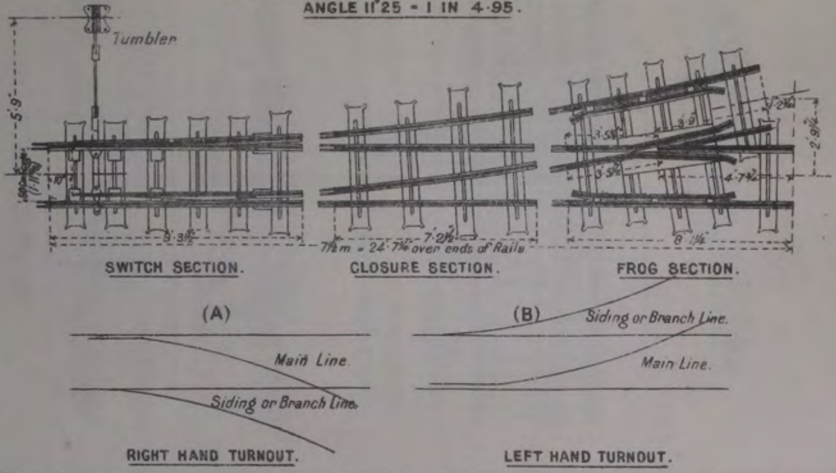
20-lb. TURNOUT. 30 m. RADIUS.

ANGLE 11°25 = 1 IN 4·95.



1709.
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MULE WALK 20-LB. TRACK

FIG. 1

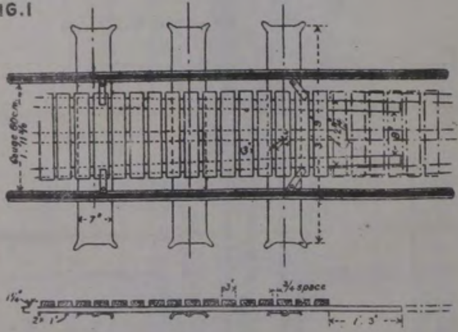
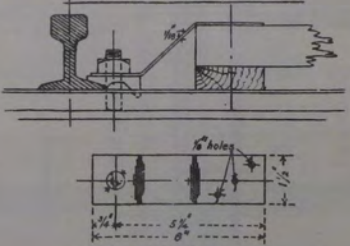


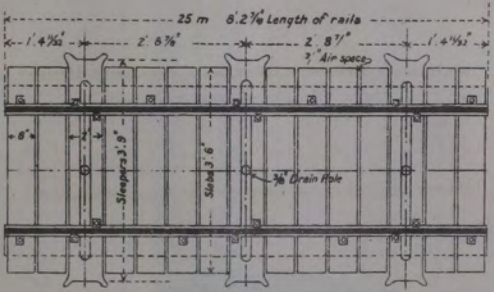
FIG. 2.

DETAIL OF HOLDING DOWN CLIP.

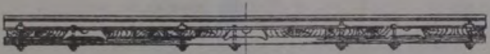


Can be made from Hoop Iron taken from Corrugated Iron Binding.

RAFT 20-LB. TRACK.



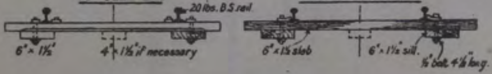
PLAN.



ELEVATION.

SECTION SHEWING ATTACHMENT TO SLEEPERS

SECTION SHEWING ADDITIONAL TIMBER SLEEPERS



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CROSS SECTIONS OF EARTHWORKS.

FIG. I.

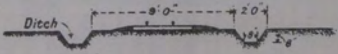


FIG. 2.

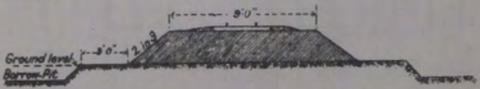
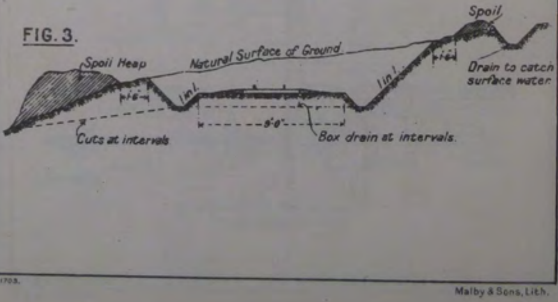


FIG. 3.



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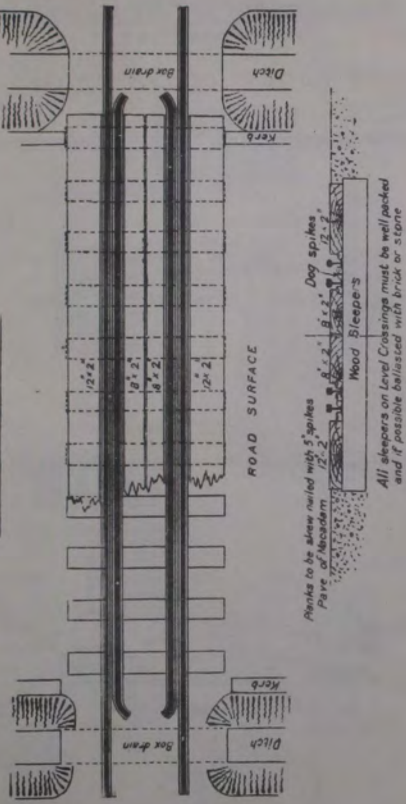
LEVEL CROSSING.



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DEMOLITIONS. USE OF FUZE INSTANTANEOUS. DETONATING.

FIG. I.

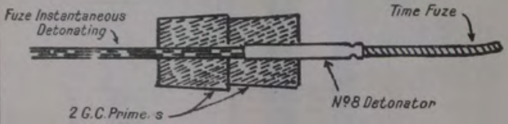


FIG. 2.

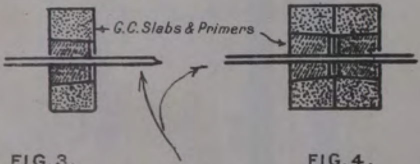


FIG. 3.

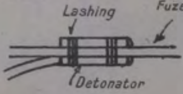


FIG. 4.

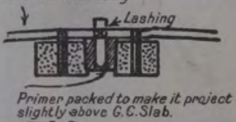


FIG. 5.

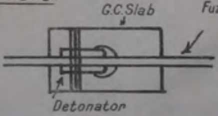
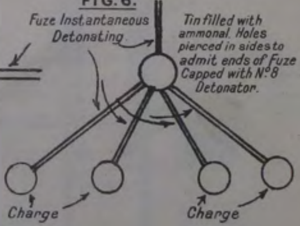


FIG. 6.



DEMOLITIONS.

METHOD OF FIXING CHARGES TO GIRDERS.

FIG. 1.

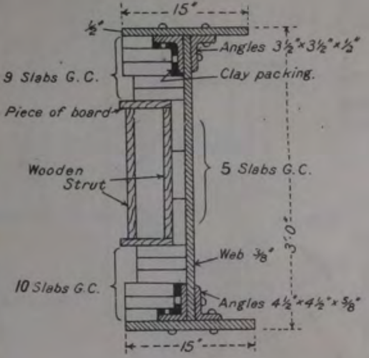
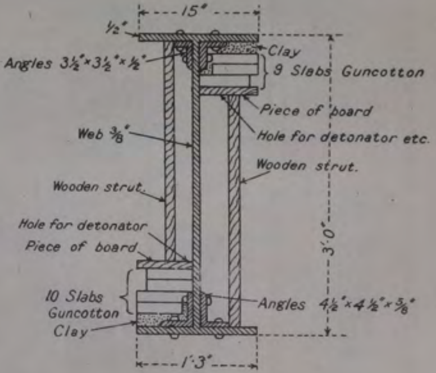


FIG. 2.



Thickoess of rivet heads ½" throughout.

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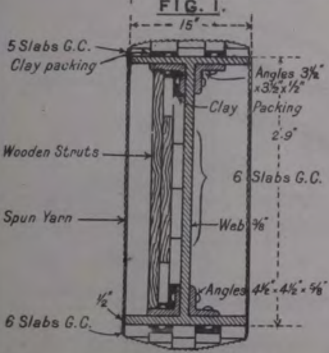
See Sec. 119, 2.

DEMOLITIONS.

(METHOD OF FIXING CHARGES AND DETONATORS)

FIG. 1.



Thickness of rivet heads ½" throughout

FIG. 2.

FIG. 3.

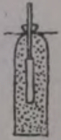


FIG. 4.

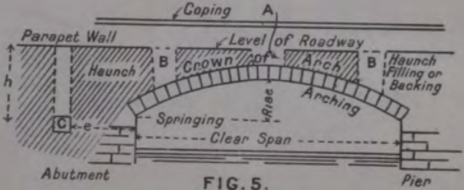


FIG. 5.

A Charge at Crown
B.B Charges at Haunches
C Charge at Abutment

[See Sec. 114, 6 and 7; 119, 2; 121, 1.

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1703

DEMOLITION OF RAILWAYS.

See Secs. 114, 7; 119, 1; 122, 2.

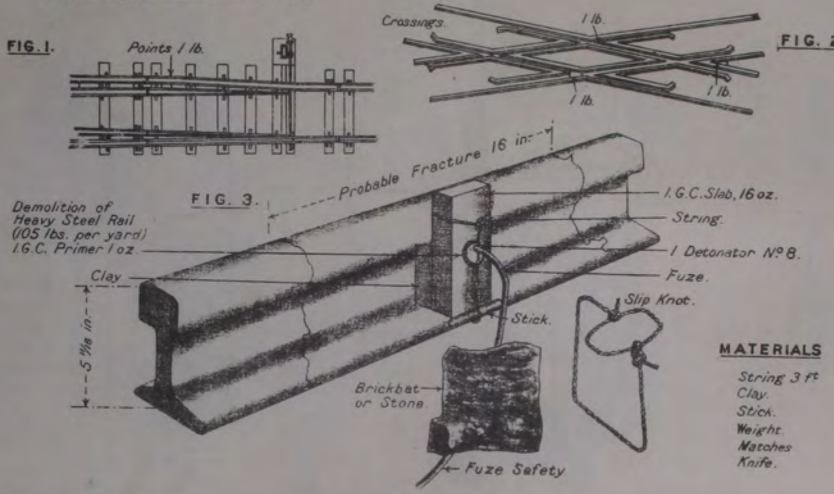
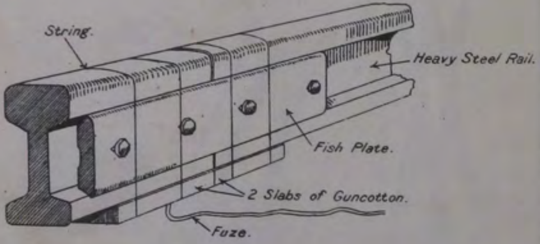


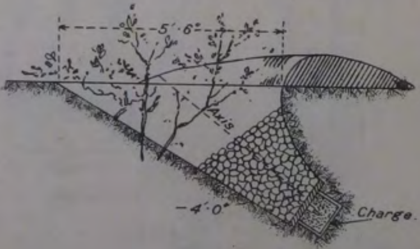
Plate 175.

Malby & Sons, Lith.

DEMOLITION OF RAILWAYS.



F O U G A S S E.



ELECTRIC FIRING.

JOINTING WIRES.

FIG. 1.

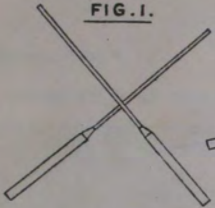


FIG. 2.

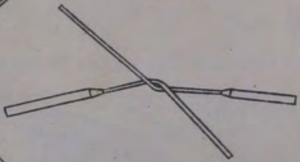


FIG. 3.

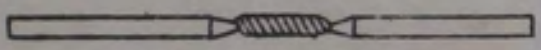
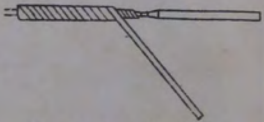
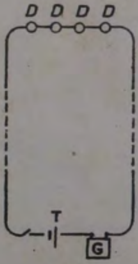


FIG. 4.



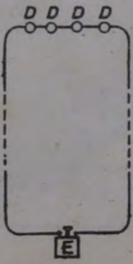
Connections for testing

FIG. 5.



Connections for firing

FIG. 6.

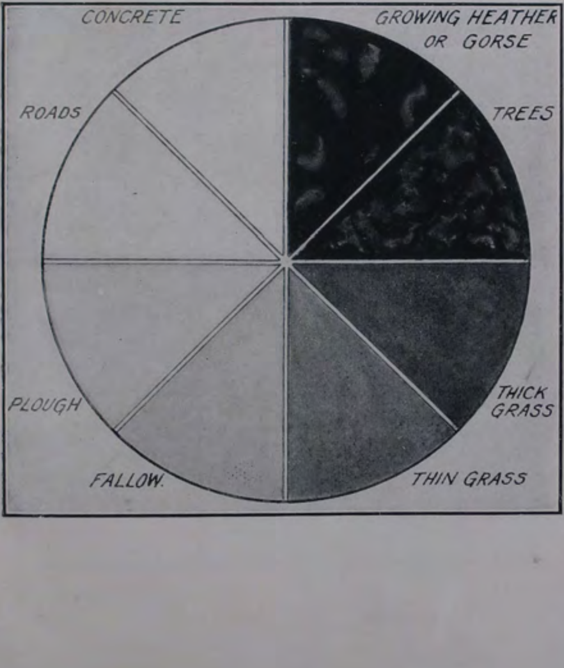


D.D. = Detonators in charge.
T = *Test Cell.*
G = *Q & I. Detector.*
E = *Exploder.*

Malby & Sons, Lith.

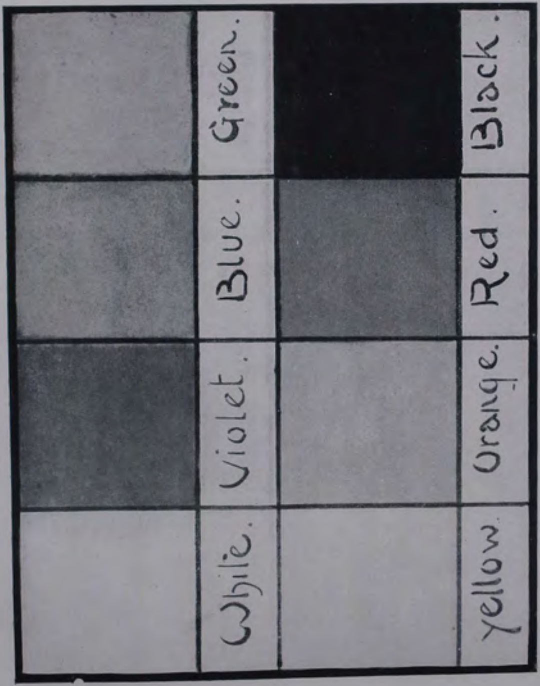
See Appendix X. Sec. 5, 5.] PLATE 178.

THE RELATIVE TONE VALUES OF LANDSCAPE SURFACES.



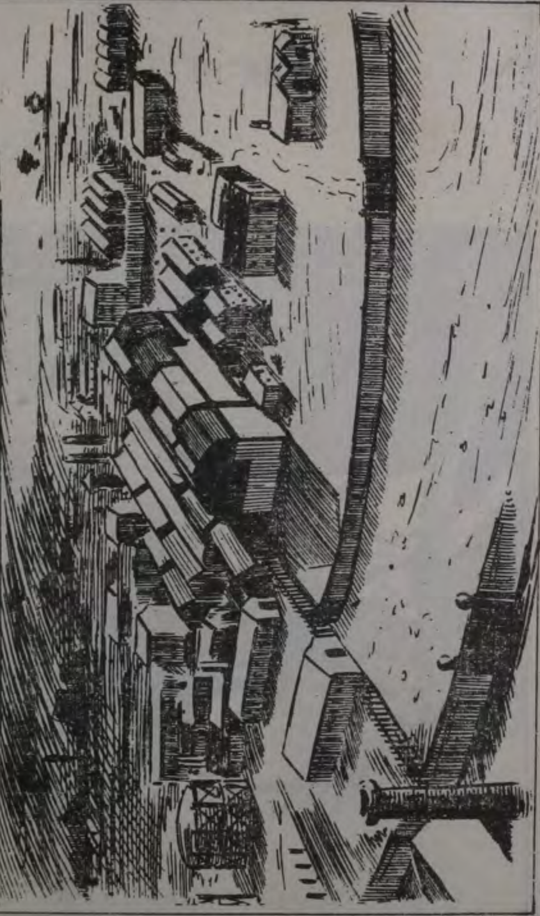
See Appendix X. Sec, 5, 6.]

TONE VALUES OF COLOURS.



(B 28/277)Q

DISRUPTIVE PAINTING OF LARGE BUILDINGS



Method of concealing very large building, by dividing it up into small rectangles

1702.

Malby & Sons, Lith.

TRACKS.

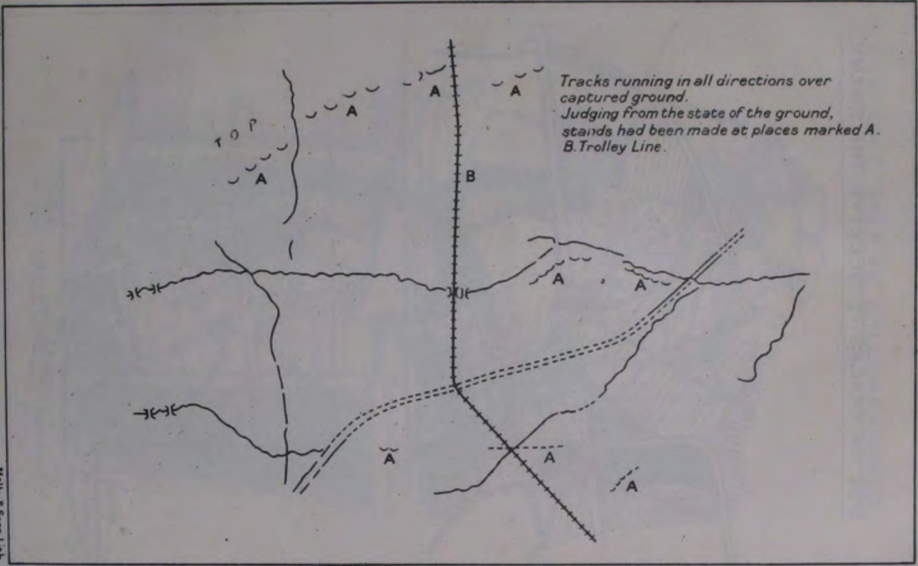
1703.

Malby & Sons, Lith.

PLATE 182 (*For key, see Plate facing.*) [*See Appendix X. Sec.* 4, 3.

TRACKS.

1703.



(Key to Plate 182.)

Malby & Sons, Lith.

USE OF TRACKS TO DECEIVE THE ENEMY.

FIG. I.

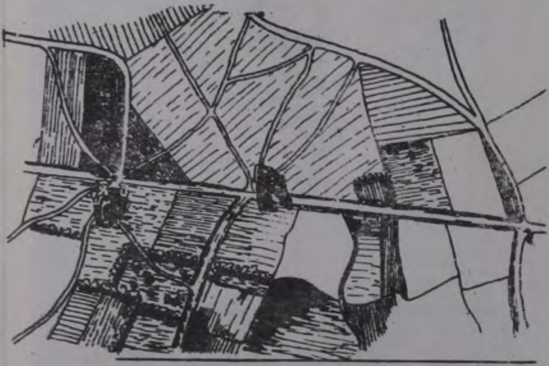


FIG. 2.

KEY TO FIG. I.

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PORTABLE "BEEHIVE" O.P. UNARMOURED.

FIG. I.
SHOWING BRICK CAMOUFLAGE.

FIG. 2.
IN USE.

Malby & Sons, Lith.

THE "ROLAND" O.P.

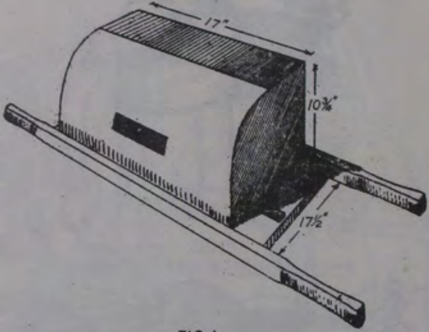

FIG. 1.

STEEL SHIELD WITHOUT CAMOUFLAGE.

FIG. 2.

Malby & Sons. Lith.

THE "OLIVER" O.P. & CABIN.

FIG.I.

Bullet-proof steel front
Without Camouflage

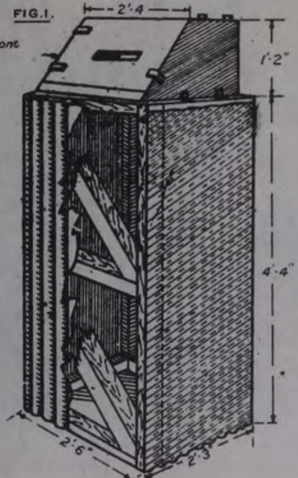

FIG.2.

Camouflage earth front for the Oliver O.P.

FIG.3.

Camouflage sandbag front for the Oliver O.P.

Melby & Sons, Lith.

CAMOUFLAGE COVER FOR CONSOLIDATED SHELL HOLE.

Showing Section of Crater with Screen of distempered canvas or American cloth in position over alteration to Shell hole.

FIG. 1.

FIG. 2.

1703

CAMOUFLAGE COVER FOR MACHINE GUNS AGAINST AIR RECONNAISSANCE.

[See Appendix X, Sec. 6, 2.]

Note:- Consists of scrim canvas patches and green knots for use in grass and chalk country.

Plate 188.

Malby & Sons, Lith.

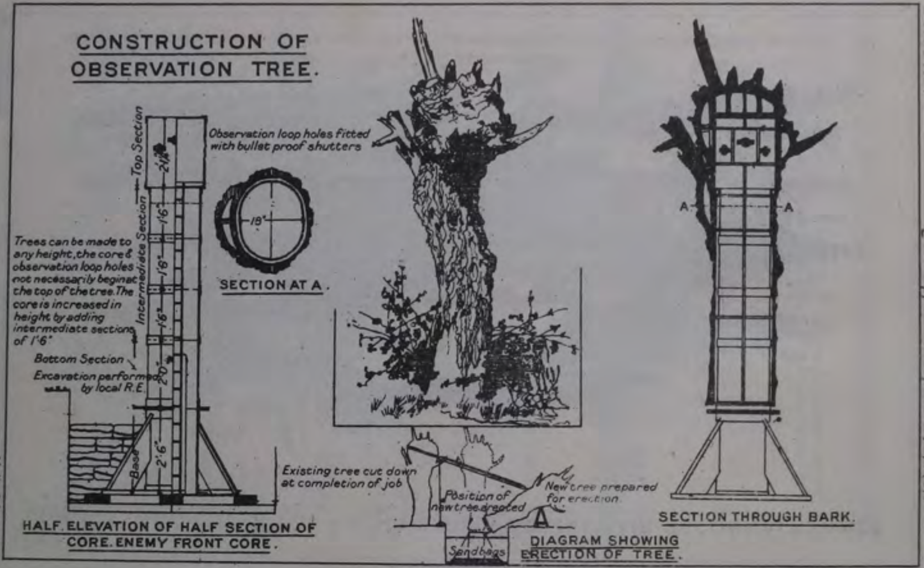

Plate 189.

[See Appendix X, Sec. 6, 5, ii (b).

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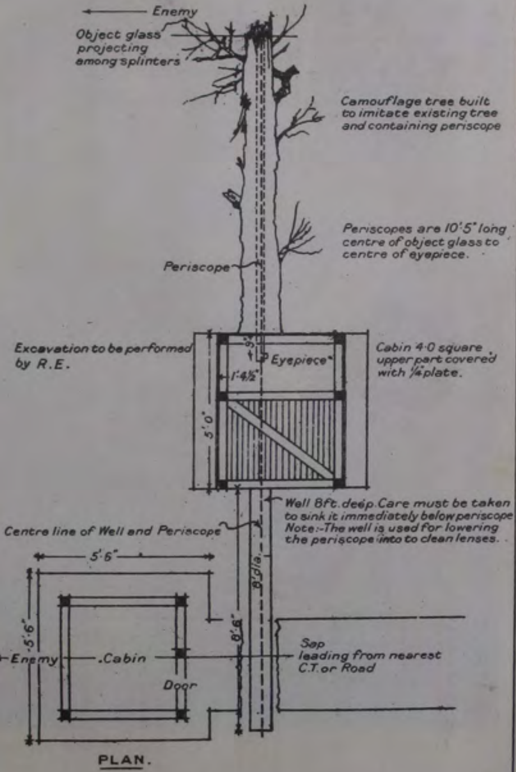
TYPICAL ARRANGEMENT OF PERISCOPE TREE.



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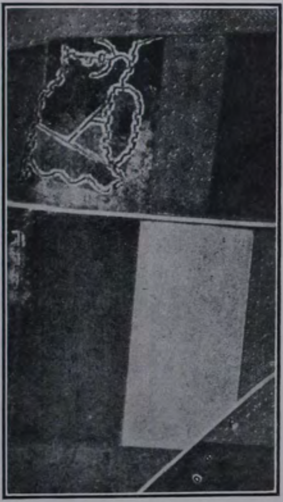
A BADLY SITED AND CONCEALED BATTERY POSITION.

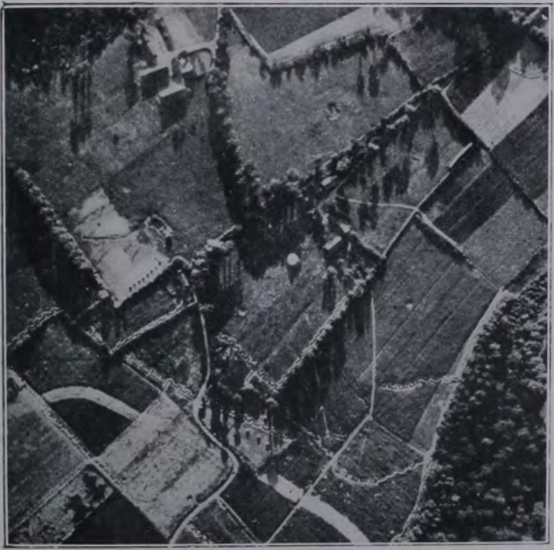
See *Appendix X. Sec.* **7**, 3.] PLATE 192.

BATTERY POSITION ON SMOOTH BACKGROUND.



See Appendix X. Sec. 7, 3.] PLATE 193.

BATTERY POSITION IN BROKEN BACKGROUND.



See Appendix X. Sec. 7, 7.]

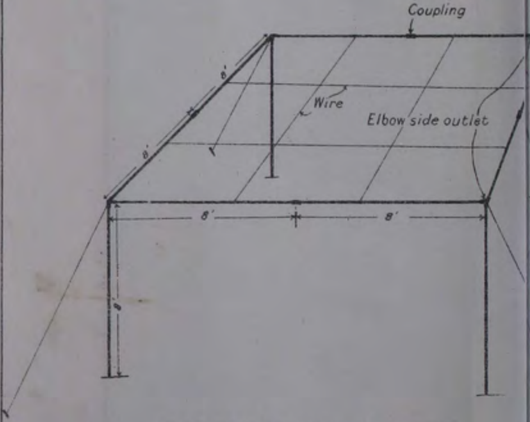
USE OF NATURAL CAMOUFLAGE.

A 6-INCH HOWITZER BATTERY COVERED WITH BRUSHWOOD.

Malby & Sons, Lit.

See Appendix X, Sec. 7, 9.]

WIRE N



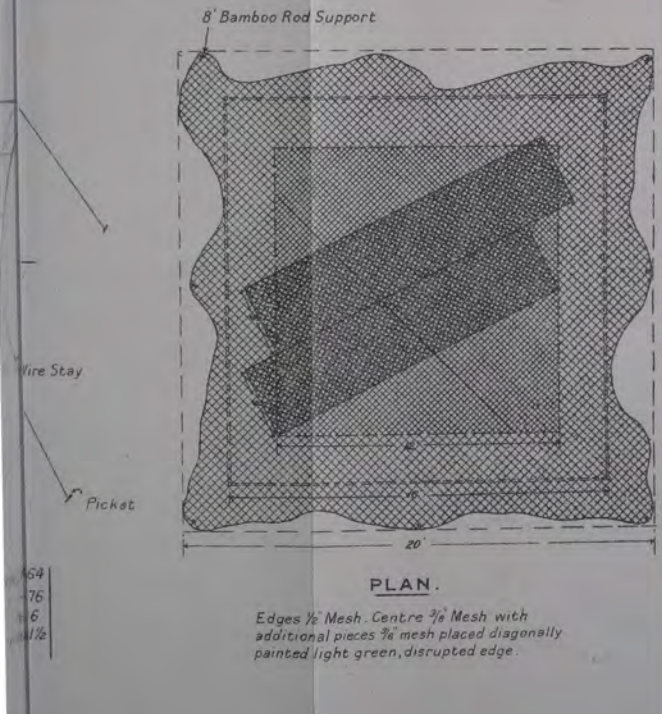
PERSPECTIVE VIEW OF FRAME.

Stores.

Gas Piping, 1" 8 ft. lengths	No.	12	Wire Netting, ½" mesh, 4' wide	
Couplings, 1"	No.	4	" " ⅜" " 3' "	
Elbow, side outlet	No.	4	Paint, Dry.	
Wire, Galvanised, No. 14 S.W.G.	Feet	140	Oil, boiled	pir
Bamboo Rods	No.	8		

1703.

...TTING COVER.



PLAN.

Edges ½" Mesh. Centre ⅜" Mesh with additional pieces ⅜" mesh placed diagonally painted light green, disrupted edge.

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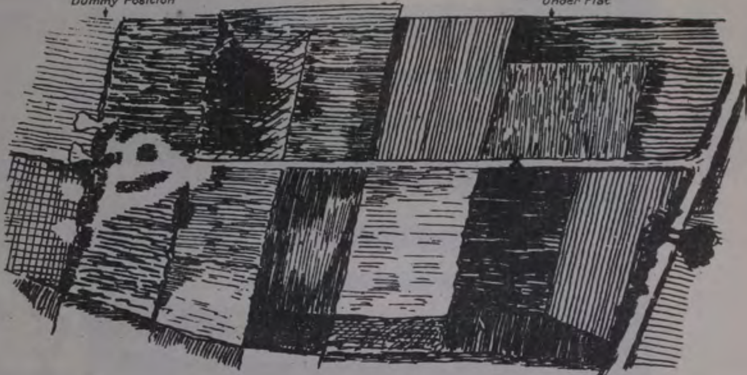
DUMMY BATTERY POSITION.



Traffic to battery unloaded at X continues to dummy position and turns round there, thus keeping the tracks well worn.

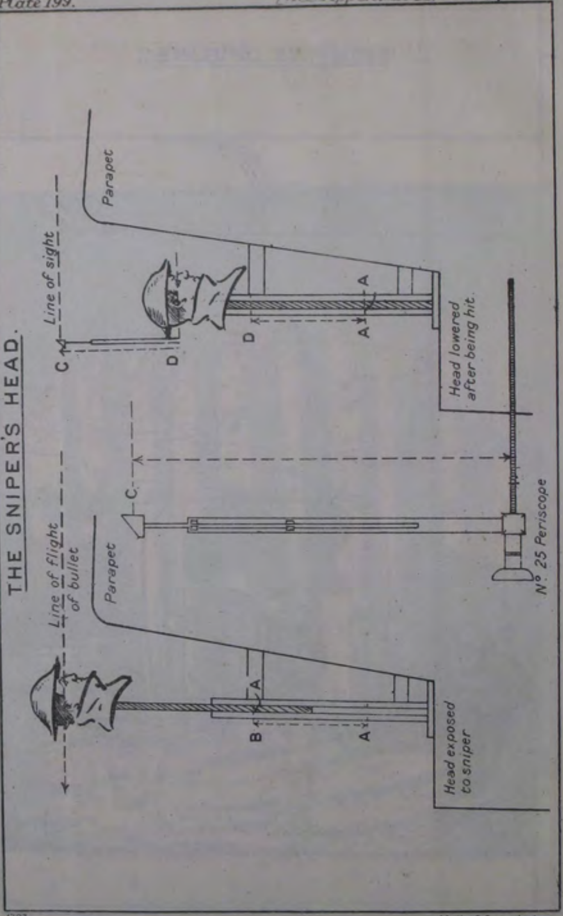
PAINTING OF GUNS.

1703.

Malby & Sons, Lith

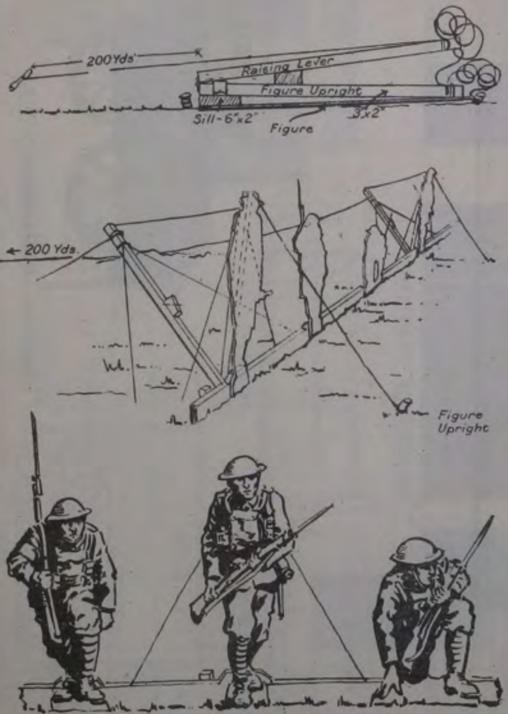
PAINTING OF GUNS.

1703 Malby & Sons, Lith.



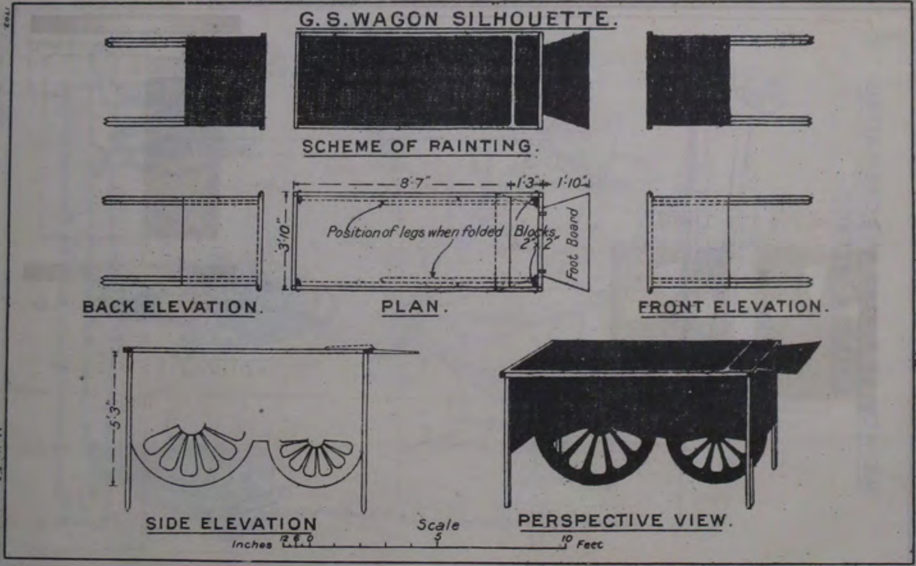
Malby & Sons, Lith.

METHOD OF FIXING AND OPERATING CHINESE ATTACK.



19 Figures (spaced irregularly) per 50 Yds. Operated by 3 Men

Plate 201.



[See Appendix X, Sec 8 3.

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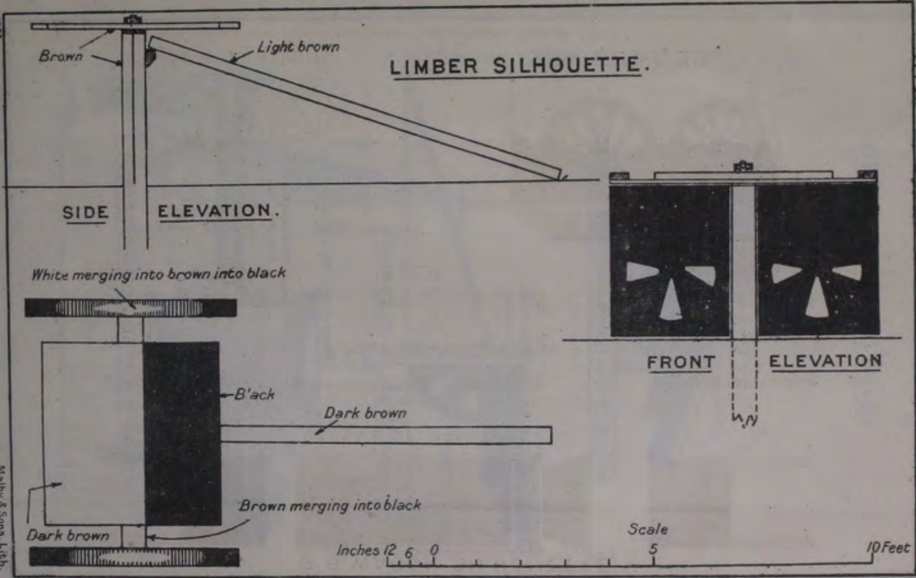
LIMBER SILHOUETTE.



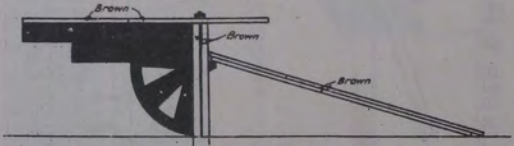
See Appendix X, Sec. 8, 3.

Plate 202.

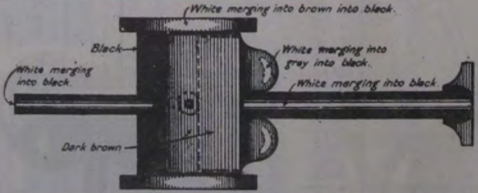
Malby & Sons, Lith.

18 PDR. GUN SILHOUETTE.

PROJECTION SHOWING "DROP SCREENS"

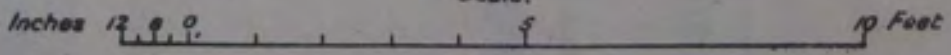


SIDE ELEVATION

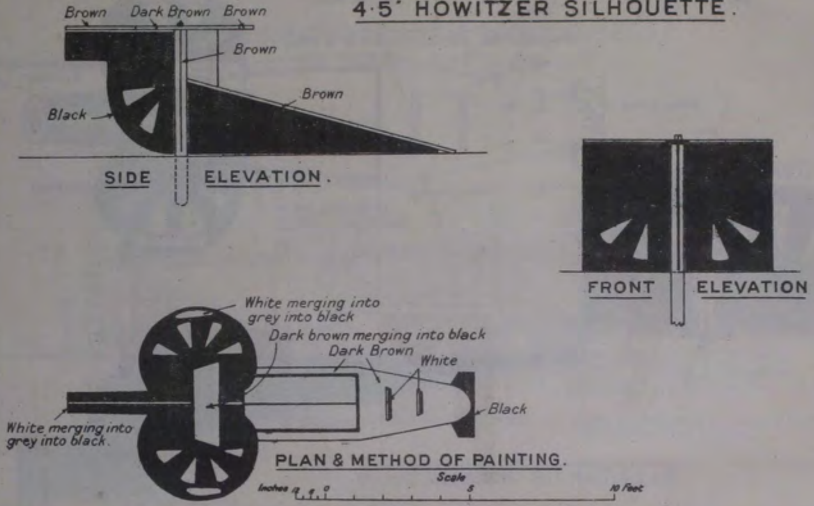


PLAN & METHOD OF PAINTING.

Scale.



4·5" HOWITZER SILHOUETTE.



[See Appendix X, Sec. 8, 3.]

Plate 204.

Malby & Sons, Lith.

6" HOWITZER SILHOUETTE.

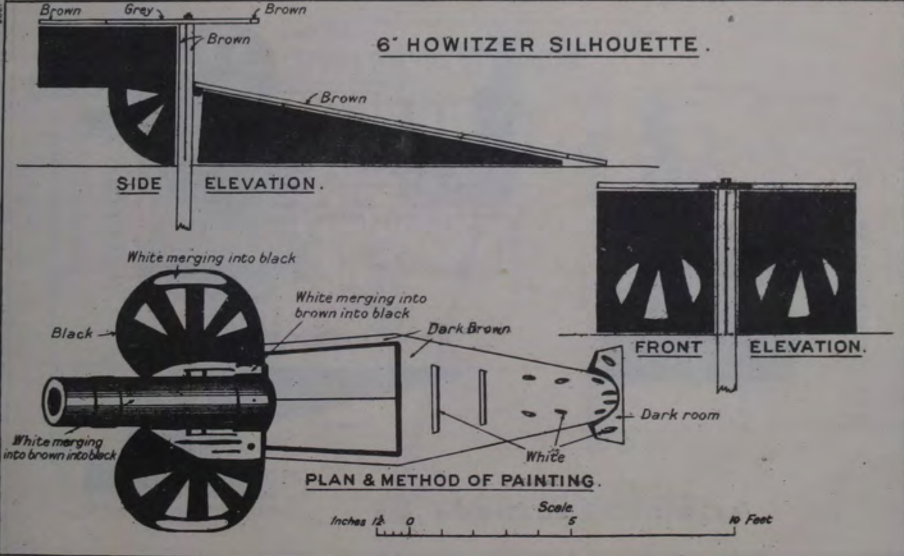


Plate 205.

[See Appendix X, Sec. 8, 3.

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[See Secs. 28,3; 61,8; Appendix XI.]

SECTION OF STONE & EARTH SANGAR TO RESIST SHELL FIRE.

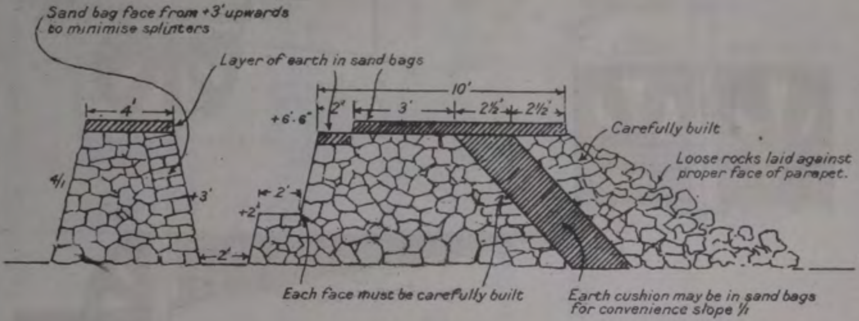


Plate 206.

Malby & Sons, Lith.

SANGAR PIQUET POST.

PLAN

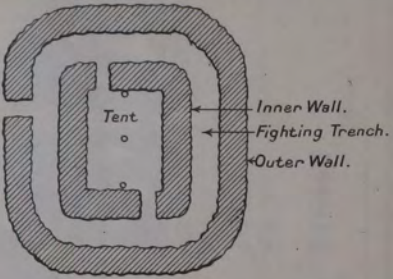
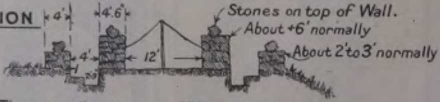


FIG. I.

SECTION



Tie tent walls to stones. The wall of the tent is placed on the inside of the inner wall to catch bombs & ensure bombs not rolling into fighting trench.

FIG. 2.

VIEW OF PIQUET.

Top of tent coloured to prevent silhouetting.

FIG. 3.

SECTION ON SLOPING GROUND.

1703

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Part II. 1914. Instructions for Laboratories and Laboratory Operations, Examination of Explosives and Ordnance. (Reprinted with Amendments published in Army Orders up to and including Dec. 1, 1916.) 1s. 6d.

Pathological Specimens in the Museum of the Army Medical Depart., Netley. Descriptive Catalogue of Third Edition. Vol. I. By Sir W. Aitken, M.D., 1892. 5s.

Pay, Allotments of. *See* SEPARATION ALLOWANCE.

Royal Warrant for the Pay, Appointment, Promotion, and Non-effective Pay of the Army, 1922. Issued with Army Orders for July 1922. 2s.

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Rifles, Short and Charger-loading, Magazine, Lee-Enfield. Handbook for Serjeant-Instructors of Special Reserve, Officers' Training Corps, and Territorial Force in regard to the Care, Inspection, &c., of 3d.

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Section Leading in Attack and Defençe, 1923. 2d.

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[*Notified in Army Orders for February*, 1928.

MANUAL OF FIELD WORKS (ALL ARMS), 1925

AMENDMENTS (No. 2)

1. Page 109. Section 85, paragraph 6, line 5.—*For* " bridge-carrying " *substitute* " bridging."

2. Page 110. Section 85—

   Paragraph 8.—*Add* at end—

   " For crossing by night, if the slats have not been whitewashed, tracing tapes should be laced along the outer edges of the trench boards."

   Paragraph 9, line 2.—*For* " carrying " *substitute* " bridging."

   Lines 3 and 4. *For* last sentence *substitute*:—

   " In crossing these bridges troops should not double but should walk."

   Lines 5 and 6.—*For* " bridge-carrying " *substitute* " bridging."

3. Page 115. Section 88, paragraph 4, line 21.—*After* " current," *insert*—

   " Lines through float handles prevent a broken trench board causing a wide gap in bridge."

4. Page 107, Section 84, paragraph 3 (as amended by Amendments No. 1) :—

   Delete sub-para. i (*a*) and *substitute*—

   " (*a*) About 416 ft. of assault bridge material (Kapok float)."

   Delete sub-para. ii (*a*) and *substitute*—

   " (*a*) About 832 ft. of assault bridge material (Kapok float)."

   Insert new sub-paragraph—

   " iv. With a field squadron—

   (*a*) About 208 ft. of assault bridge material (Kapok float).

   (*b*) Pontoon equipment (Consuta wood) to construct 105 ft. of medium bridge (*i.e.*, 4 piers and 5 bays of superstructure)."

57-9999.

[*Notified in Army Orders for May, 1932.*

MANUAL OF FIELD WORKS (ALL ARMS), 1925

26
Manuals
1166

AMENDMENTS (No. 5)

Page 165. Section 115, paragraph 6.

Delete the amendment promulgated by Amendments No. 3, notified in Army Order 190 of 1928 and *substitute*—

" The ' Cell, Inert, S, Mk. I ' is used to provide the current. This cell is sufficiently powerful to fire a detonator, and must never be used unless contained in a ' Box, Safety Test, Cell S, Mk. I.'

The ' Box, Safety Test, Cell S, Mk. I,' is a teak box, with two terminals, incorporating a resistance of 12·2 ohms.

Instructions for its use are engraved on an ivorine plate fitted on the outside of the box, and are also printed on paper labels pasted inside the lid of both the ' Box, Testing and Jointing ' and ' Cases, Testing, Field.' These should be carefully read before use.

A ' Box, Safety Test, Cell S, Mk. I ' with a ' Cell, Inert, S Mk. I ' and a 3-coil galvanometer (vocabularized as Detector Q and I) are provided in both the ' Box, Testing and Jointing ' and ' Cases, Testing, Field.' "

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[OFFICIAL COPY.]

[*Notified in Army Orders for October*, 1928

MANUAL OF FIELD WORKS (ALL ARMS), 1925
AMENDMENTS No. 3

Section 115, page 165, paragraph 6. *Delete* from "A special" in line 5 to "jointing" in line 1 on page 166, and *substitute*— 57 Engineers 1079

Amdt. 3. Oct., 1928. "A "Cell, inert, S" is used to furnish the current and is contained in a "Box, resistance, Cell S", connected in such a manner that sufficient current cannot be produced to fire a detonator.

The use of a "Cell, inert, S" without its "Box, resistance, Cell S" or any other type of cell is highly dangerous.

A "Box, resistance, Cell S" and a 3-coil galvanometer are provided in the "Box, testing and jointing""

By Command of the Army Council,

H. J. Creedy

THE WAR OFFICE,
31*st October*, 1928

LONDON:
PRINTED & PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
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1928.

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