By Authority.

TEXT BOOK
ON
FORTIFICATION ETC

COLONEL G. PHILIPS. R.E.

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FORTIFICATION, ETC.,

FOR THE USE OF THE

ROYAL MILITARY COLLEGE, SANDHURST.

BY

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FOURTH EDITION.

By Authority.

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PREFACE TO THE FOURTH EDITION.

THE Author's return from a six years' tour of foreign service at the end of last year coincided with the exhaustion of the Third Edition, which rendered necessary the immediate issue of a new one.

The alteration of the size of the work, so as to correspond with other books issued officially, or by authority, and the change made in the illustrations, have been done at the request of the Authorities.

Endeavours have been made to place the work in harmony with the "Instruction in Military Engineering" and the "Manual of Field Engineering," issued at the School of Military Engineering, Chatham, both of which works have come into existence since this book was first published; also with the "Text Book on Fortification, &c.," used at the Royal Military Academy, Woolwich. This point, so desirable in many respects, is specially so at the present time, when officers in all parts of the world have to prepare themselves for examination in military subjects, and frequently with a difficulty in obtaining the necessary text books.

A few days after the work was handed over to the printers, their premises were destroyed by fire, which also destroyed all the wood blocks of the illustrations of the former Edition, together with much of the matter of the present one.

Under the press of work thus thrown on him, the Author gratefully acknowledges the assistance afforded to him by the authorities of the School of Military Engineering, Chatham, and of the Royal Military Academy, Woolwich. His best thanks are also due to Colonel H. Schaw, R.E., from whose work on the "Defence and Attack of Positions and Localities" much of the matter of Chapter X. has, by permission, been extracted.

LONDON, *August*, 1884.

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SECTION I.

GUNPOWDER, ARTILLERY, ETC.

GUNPOWDER: *its composition and action; object of granulation; various kinds in the Service.*—CARTRIDGES *for Ordnance.*—GUN COTTON: *how prepared; its special properties; discs and slabs.*—ARTILLERY, *definitions.*—ORDNANCE, *rifled; advantages gained by rifling; use of elongated projectiles.*—SERVICE RIFLED ORDNANCE: *the three types—Armstrong (B. L.) Guns; M. L. (Woolwich) Guns; Recent B. L. Guns; general mode of manufacture; system of rifling.*—PROJECTILES FOR R. O.—SHELLS: *Common, Palliser, or Battering, Shrapnel; Case Shot; Segment Shells (Armstrong's).*—GAS CHECKS, *two uses of.*—TUBES.—FUZES: *Time and Percussion; S. B. O. still in use; Mortars; B. L. Guns (S. B.).*—ROCKETS: *Signal and Hale.*—CARRIAGES FOR ORDNANCE: *general classes of; examples of each type.*—VARIOUS KINDS OF ARTILLERY FIRE, *with reference* (1) *to direction, and* (2) *to elevation of piece.*—THE INFANTRY RIFLE *and its Ammunition.*—PENETRATIONS OF RIFLE BULLETS.—MACHINE GUNS: *Gatling and Nordenfelt Guns.*

GUNPOWDER.

1. *Gunpowder* is an intimate mixture of *Nitre* or *Saltpetre*, *Sulphur*, and *Charcoal:* the proportions of the several ingredients in the powder used by various Governments are here annexed:

	Nitre.	Sulphur.	Charcoal.
England	75	10	15
France .... / Prussia .... / United States	75	12·5	12·5
Russia	73·78	12·63	13·59
Austria	76	12·5	11·5

When a burning body is brought into contact with some of the grains of a charge of powder, these take fire; and, owing to the nature of the ingredients, the intimate manner in which they are mixed together, and the air spaces between the grains, the combustion spreads through the mass so rapidly as to be almost instantaneous; and the result is the sudden production of a quantity of an elastic gas in a highly condensed state.

The force exerted by this gas in expanding in every direction possible at the moment of its generation is used in fire-arms for propelling the various projectiles in use. Being confined by the metal of the gun from expanding in any direction but that of the bore of the piece, a charge of powder when fired in a gun of any kind acts in a two-fold manner—viz., by forcing the projectile in one direction out of the bore of the gun, and by causing the gun itself to recoil in the opposite direction.

2. The combustion of gunpowder is principally effected by the combination of the charcoal (carbon) with the oxygen of the saltpetre, the result of which is the formation of carbonic acid gas and carbonic oxide, and the setting free of the nitrogen in the saltpetre. The sulphur, at the same time, combines with the potassium of the saltpetre, forming sulphate and sulphide of potassium, and serves to increase the heat of the gases generated, and thereby their elasticity at the moment of firing.

Generally speaking, it may be said that the object of the charcoal is to supply the body to be burnt; that the saltpetre supplies the oxygen necessary to support the combustion; and that the sulphur serves principally to increase the expansive force of the gases by raising their temperature, and by rendering the action more rapid, as it takes fire at a much lower temperature (560° to 600° F.) than do the other ingredients.

3. The explosive force of gunpowder depends on three things—(1) The amount of gas generated, (2) the heat to which it is raised, and (3) the rapidity with which it is formed.

The most reliable researches result in determining that the permanent gases generated at 0° C. occupy 280 times the volume of the original powder, and that they form 43 per cent. by weight of the original powder; also that the temperature of explosion is about 2,200° C. or 4,000° F.

The chief gaseous products are carbonic acid, carbonic oxide, and nitrogen.

The rapidity of the explosion is much affected by the size of the grains, or lumps, of the charge.

This is a most important point affecting the explosiveness of gunpowder. Although a charge of gunpowder appears to explode instantaneously, yet both *ignition* and *combustion* are gradual: the flame is communicated from one grain to another, each burning in concentric layers until it is consumed, so that the combustion of the grains is not simultaneous.

The rate of *ignition* of a given charge depends principally on the air space between the grains, which allows the flame to pass from one grain to the next, and so through the mass, more or less rapidly.

The rate of *combustion* depends principally on the size of grain and on its density; largeness of grain causing the time of combustion to be increased, and an increase of density having a similar effect.

Consequently, by regulating the size of grain, or lump, of charges of gunpowder, it is practicable to regulate the rate of explosion in a desired manner; and also by having the bore of a gun of a length suitable to develop the full effects of a given charge, it is possible to obtain a high velocity to a projectile without undue strain on the gun. This important point is now fulfilled with the various Service guns.

For small arms, which are practically indestructible from the effects of their own fire, and with which the charges are very small, small grain powder is used, as the combustion is required to be rapid; but for heavy rifled guns, where very large charges are used, and where the stress on the gun is very severe (as much as 25 tons per square inch), it is necessary to render the explosion progressive, and so develop the required velocity to the projectile gradually, with a minimum strain. And this is effected by proportioning the size of grain for the charges of various classes of guns, according to the weight or bulk of the charge itself. (See table of Service Ordnance for list of charges used.)

4. All the powder in use in the Service is of the same composition, and varies for different purposes only in the size, shape, and density of the grains.

The following is a list of the principal powders now in use :—

Description of Powder.	Size and Shape of Grain.	Density.	For what Purposes Used.	Remarks.
Prismatic	Hexagonal; size, various; 1″ height and 1⅓″ diameter, with central hole ·39″ diameter.	1·75	80 and 100 ton guns and larger calibres	Pressure on gun from 20 to 22 tons per sq. inch.
"P_2" (Cubical)...	1½″ cubes	1·75	9″, 10″, 11″, and 12″ guns	
"P" (Pebble) ...	⅝″ cubes	1·75	64 pr. M. L. and 40 pr. B. L., and guns up to 8″ M. L.	
R. L. G_2	3 to 6 mesh ...	1·66	For guns up to 40 pr. B. L. and M. L.	
R. F. G_2	12 to 20 mesh ...	1·72	Martini-Henry rifle and Machine guns	

5. *Cartridges for Ordnance* are made up in bags of silk cloth, which material combines the properties of being of sufficient strength to stand wear and transport, and of being totally consumed and leaving no smouldering particles in the gun after being fired.

Each cartridge has distinguishing marks on its exterior by which its weight the gun it is intended for, &c., are evident.

Gun Cotton.

6. *Gun Cotton* is an explosive that is used principally as a destructive agent, such as in the charges of torpedoes, and for demolitions of all kinds, especially hasty ones; but it is not used as a propelling agent in addition, as is the case with gunpowder.

Gun cotton is prepared by steeping cotton waste (thoroughly cleansed) in the strongest nitric acid. The cotton, while remaining unchanged in outward appearance, increases (about 70 per cent.) in weight, and undergoes a marked chemical transformation, and becomes gun cotton, which has many special properties.

The gun cotton thus prepared is, after being cleansed, reduced to a pulp, and in this state is moulded and pressed into the forms required.

7. Among the remarkable properties possessed by gun cotton are the following, which are especially useful for military purposes :—

When dry and unconfined it will not explode if ignited by a flame or heated body, but merely burns rapidly. If, however, it be confined in a strong case, the action is very different; it then explodes with great violence, and the strength of the explosion depends on the thickness of the case: to develop it fully a strong iron case is required, such as is used for the charges of submarine mines.

Compressed gun cotton may be *detonated*, even when unconfined, by the action of various detonating bodies, of which fulminate of mercury is the most suitable. When detonated the explosion of gun cotton is *extremely rapid* and *violent*, but at the same time the effect is greatly local. It is this property which renders it such a valuable agent for destruction, although it prevents its use as a propellent.

Wet compressed gun cotton is, by itself, uninflammable, but it can be detonated provided a small "primer" of the dry material, in contact with it, is itself detonated—*i.e.*, fired by some kind of detonating fuze. This enables gun cotton to be kept stored in a wet state and perfectly harmless; while it can be used in that state, if fired, as above described, by a dry "primer."

The explosive force of gun cotton is about four times that of gunpowder.

8. *Forms of Service Gun Cotton.*—Except when gun cotton in the form of yarn is used as a primer for fuzes, it is universally employed compressed into slabs or discs of different dimensions and weight, from $2\frac{1}{2}$ lb. down to 1 oz., according to the purpose for which it is required. The pressure used in the manufacture is 4 tons to the square inch. These slabs, or discs, for the most part have holes bored in them, while in the wet state, to receive the *detonator*, or small metal tube containing the charge of fulminate of mercury.

The slabs are about 6 inches square, and from $1\frac{1}{8}''$ to $1\frac{3}{4}''$ thick, and weigh from $1\frac{1}{2}$ to $2\frac{1}{2}$ lb.

The discs vary in size from a diameter of $1\frac{1}{4}''$, weighing 1 oz., to a diameter of 3″, weighing 8 to 9 oz.

The discs and slabs can be used either singly, or threaded or sewn together in any number: thus a *necklace* of them can be used for blowing a gap in a wall or stockade, or for cutting down trees, &c. Large charges of gun cotton are confined in suitable cases.

9. Definitions in Artillery.

The *Axis of a Gun* is an imaginary line passing through the centre of the bore, as E B (Fig. 1).

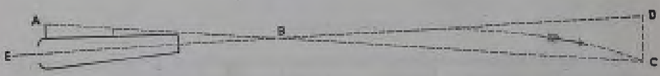


Fig. 1.

The *Calibre* is the diameter of the bore in inches. In rifled pieces it is measured across the lands.

Windage is the difference between the sectional area of the gun through its grooves, and that of the body of the projectile through its studs. With gas checks there is practically no windage when the gun is fired.

Clearance is the linear distance between the body of the projectile and the bore of the gun. This was formerly called the windage.

The *Line of Sight* is the visual line passing through the two sights used (at any elevation) and the object; when the gun is laid, as A B C (Fig. 1), where C is the object.

The *Line of Fire* is the imaginary line from the muzzle of the piece to the point aimed at.

The *Angle of Elevation of a Gun* is the angle formed between the line of sight and the axis of the gun, as A B E or D B C (Fig. 1). That *of a Mortar* is the inclination of its axis to the horizontal plane.

The *Range* is the distance from the muzzle of a gun to the second intersection of the trajectory with the line of sight, as B C (Fig. 1). In practice the range is usually measured from the muzzle of the gun to the first graze of the projectile.

Point Blank. A gun is said to be laid *point blank* on an object, when the line of sight is parallel to its axis: practically this means that the axis produced passes through the object.

Initial, or Muzzle, Velocity is the velocity (always stated in feet per second) with which a projectile issues from the bore of a gun.

Final, or Remaining, Velocity is the velocity at any given range.

ORDNANCE.

10. *Smooth-Bore Ordnance* are practically obsolete, and will not be specially referred to here, although some pieces remain mounted at various stations, and certain special pieces are being utilized for particular purposes, such as flanking the ditches of forts, as described in Articles 55, 56.

Before describing the present Service Rifled Ordnance, a short explanation of the advantages of the *Rifle System* is given, as an illustration of the vast superiority of rifled weapons (small arms as well as ordnance) over smooth bores for nearly every purpose of war.

11. Smooth-bore guns have the two following great defects:—

(1) Inaccuracy of Fire.
(2) Shortness of Range.

12. Inaccuracy of fire is principally due to the evil effects of *windage*, or the space between the projectile and the bore of the gun. In loading, the projectile (which is necessarily spherical) rests on the bottom of the bore, and the windage at the moment of firing is above the projectile. When the gun is fired, the rush of gas through the windage forces the projectile downwards at the same time that it is pushed onwards. The downward pressure on the projectile causes it to rebound and strike some other point in the bore, while it is also given a rotatory motion. This rebounding action goes on during the time the projectile is within the bore of the gun, which it leaves after having struck it several times at various parts. In fact, during its passage along the bore of the gun, the projectile is *never moving accurately* in a direction *coinciding with the axis of the piece*, but is always bounding from one side to the other, and at each bound it receives from its friction with the bore an irregular twisting, or rotatory, motion. The actual direction in which the projectile is moving when it leaves the piece will, as represented in Fig. 2, be away from the point of the bore last struck by it, and the position of this point will principally affect the axis of rotation; but as this position cannot be foreseen, the inaccuracy due to this cause cannot be allowed for in practice.

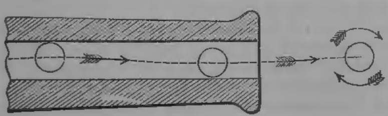


FIG. 2.

It may, therefore, be generally assumed that a smooth bore projectile never leaves the gun in the direction in which the latter is pointed; and also that its further flight is complicated by the irregular rotatory motion given to it by friction with the bore.

13. A further cause of inaccuracy is due to the eccentricity of the projectiles used. A cast iron shot or shell is always more or less eccentric—*i.e.*, its centre of gravity does not coincide with the centre of the sphere: in simpler language, one side is heavier than the other.

Now, any body which has a rotating or spinning motion tends naturally to rotate round its centre of gravity; and if, in the case of a smooth-bore shot moving through the air with a rotating motion, the projectile is eccentric (as in

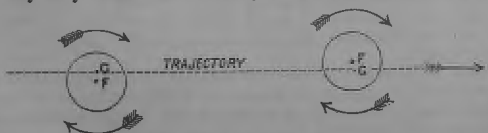


FIG. 3.

Fig. 3, where G represents the centre of gravity), it will acquire a "wobbling" motion, which not only interferes with the regularity of its flight, thus causing inaccuracy, but also tends to retard its flight, and so cause loss of range.

14. *Irregularity of form* of the projectile also to a certain extent (but comparatively to a slight extent) affects its flight, as it causes it to experience on rotation a varying amount of resistance from the air.

Hollow projectiles (shells) fired from smooth-bore guns are less accurate than solid ones, as they are not so heavy, and are therefore more easily diverted from their intended direction by wind. Nor do they range so far, owing to their small weight.

With the exception of this last-named cause, all the other causes of inaccuracy of fire from smooth-bore guns may, in any single case, be combined to cause deflection either towards one side or the other of the object, or to increase or decrease the range; while it may happen that they partly neutralize one another: they are, however, sufficient to account for the well-known fact that, if a number of shot be fired from the same gun, with equal charges and elevations, and with gunpowder of the same quality, the gun carriage resting on a platform, and the piece being carefully laid before each round, very few of the shot will range to the same distance, and the greater part will be found to deflect considerably to the right or left, unless the range be very short.

15. *Shortness of range* in a smooth-bore gun is due to the necessarily spherical form of the projectiles, which causes a rapid loss of velocity as the projectile moves through the air.

This loss of velocity arises from the comparatively small weight or mass of a spherical projectile in proportion to the surface that it opposes to the atmosphere in its passage through it; for the power of a projectile to overcome the resistance of the atmosphere is measured by its weight, while the amount of resistance, for equal velocities, may be measured by the area of its section.

An example will illustrate this: If a shot with a diameter of 8 inches be fired under precisely similar conditions of elevation and initial velocity to one with a diameter of 4 inches, the 8-inch shot will range further than the 4-inch shot; for while the 8-inch shot has a greater resistance from the air to overcome, viz., in the proportion of 8^2 to 4^2, or of 4 to 1, it has a still greater power in its weight to overcome that resistance, because the respective weights of the two shots are in the proportion of 8^3 to 4^3, or of 8 to 1.

16. Therefore, with smooth-bore guns, those of large calibre have longer ranges than those of smaller calibre (elevation and initial velocity being the same in each), because their projectiles lose their velocity at a less rapid rate. It is for this reason that a long range smooth-bore gun necessarily must be one of large calibre, and therefore of great weight.

17. The accompanying table exhibits the actual loss of velocity in solid shot from the Service S. B. Guns named, occasioned by the resistance of the air in passing over a distance of 50 feet, and fully illustrates the foregoing remarks.

Nature of Gun.	Initial Velocity.	Velocity Lost in 50 Feet.
S.B. 68 Pr. ...	1,600 Feet per Second	15·7 Feet per Second.
,, 32 ,, ...		20·4
,, 24 ,, ...		22·0
,, 12 ,, ...		27·7
,, 9 ,, ...		30·9
,, 6 ,, ...		35·0

Shells for S. B. Guns have a less range than shot for the same guns, owing to the lesser weight that they have, on account of their being hollow spheres. This causes them to lose their velocity more rapidly than a solid spherical shot does, and thus prevents their having so long an extreme range.

18. *Rifling.*—In a rifled piece the bore is provided with a number of grooves, running in a spiral direction throughout its length, with the object of giving to the projectile, which fits into them, a rotatory motion on an axis coinciding with that of the bore. The rotation will be more or less rapid, according to the degree of twist given to the grooves.

19. By the application of rifling to guns, the following advantages over smooth bores are acquired:—

1. Owing to the rapid rotation* given to the projectile in a known direction, the causes of deviation arising from windage, and from the irregular shape and eccentricity of the projectile, are almost entirely abolished.

2. Since the projectile fits the bore when the gun is fired, from its being accurately *centred*, it issues from the gun with its long axis coincident with the axis of the gun; that is to say, it commences its flight in the required direction, or that in which the gun is pointed.

These two advantages are the *principal causes of the accuracy of fire* of rifled guns.

3. The projectile being given a rapid rotation on an axis coinciding with that of the gun, does not turn over in its flight, but passes through the air in a manner similar to that of an arrow, with its head to the front.

This permits the use of elongated in place of spherical projectiles, thereby allowing an increase of weight without an increase of diameter, or of the surface which is opposed to the atmosphere during its flight: and it also allows the head, or fore part, of the projectile to be made of the form most favourable for passing through the air with the least resistance, or (as in the case of *battering* projectiles) of penetrating iron defences in the most effective manner.

Owing to these causes, rifled projectiles *lose their velocity at a much less rapid rate* than is the case with those of smooth-bore guns; and to this result is principally due the *long range* of rifled guns.

20. The use of elongated projectiles leads to the further advantages of great weight of projectile when solid ones are used, and also great capacity for holding a bursting charge of powder when shells are used, which greatly increases their destructive effects. For instance, an 8″ shell S. B. weighs 68 lb., and holds 2 lb. of powder, while the shell of an 8″ Rifled Gun weighs about 175 lb., and holds 14 lb. of powder as a bursting charge.

Further, the use of elongated projectiles enables all the projectiles of each kind of gun to be made of equal weights, a great advantage in many respects. And it may be here remarked that the accuracy of fire of hollow projectiles from rifled guns is even more accurate than that of solid ones, which is due to their weight lying near the circumference (similar to the fly-wheel of an engine), and so inducing steadiness of rotation and flight.

21. The annexed table shows the length and breadth of a rectangle in which one-half (50 p.c.) of the projectiles fired from the guns named will respectively fall. These figures show the vast advantages in range and accuracy possessed by the Service Rifled Guns, which have less error at 6,000 yards than S. B. Guns had at 800 yards range.

Range.	Length.		Breadth.	
	18-Pr. S. B. Gun.	13-Pr. R. M. L. Gun.	18-Pr. S. B. Gun.	13-Pr. R. M. L. Gun
	yards.	yards.	yards.	yards.
800 yards...	92	—	7	—
1000 „ ...	—	12·15	—	0·77
1760 „ ...	121·7	—	25·8	—
2000 „ ...	—	23·25	—	1·44
3000 „ ...	—	31·95	—	1·92
4000 „ ...	—	38·40	—	2·28
5000 „ ...	—	46·94	—	2·69
6000 „ ...	—	57·44	—	3·15

22. *Service Rifled Ordnance.*

There are three sorts of Rifled Ordnance at present in use in the Service. They are:—

(1) The Armstrong B. L. Rifled Guns, originally introduced.

* The shells of recent B. L. Guns rotate about 200 times in a second. Those of the 16-Pr. M. L. Gun about 150 times in a second.

(2) Muzzle-loading Rifled Guns, which replaced the Armstrong Guns.
(3) The present B. L. Rifled Guns, which will eventually replace those of classes (1) and (2).

Existing armaments are composed of the three classes, the distinctive features of which will be briefly referred to. They are illustrated in Plate I.

23. *Armstrong B. L. Rifled Guns* are made of coiled wrought iron. In some of the later patterns the barrel is of steel. Outside the barrel coils of wrought iron were shrunk on to obtain the strength required.

Guns on this system are fired with small charges only (about one-eighth weight of projectile). They are comparatively weak, and have not been used for armour-piercing purposes.

The system of rifling for Armstrong Guns is as follows:—The projectile is coated with lead, and is a little larger in diameter than the bore of the gun, which is provided with a large number of small grooves, of the dimensions shown in Fig. 8. At the lower end of the bore the diameter is enlarged to form a *shot chamber* (*b*, Fig. 4), and behind this is a *powder chamber* (*a*), which is not rifled, and has a diameter equal to that across the bottom of the grooves. The bore also is very slightly enlarged to within about a calibre in front of the shot chamber: the intervening portion (*c*), which has a less diameter than any other part of the bore, is termed the *grip*. The diameter of the grip is the calibre of the gun.

24. The principal parts of an Armstrong Gun are shown in Fig. 4.

The *barrel* or inner tube contains the bore, the shot chamber, and the powder chamber.

The *vent piece*, V, is of steel. When it is dropped through the vent slot, or opening in the top of the gun, to its position, and pressed by the breech screw tightly against the end of the powder chamber, it effectually closes the bottom of the bore.

The *breech screw*, *s*, fits in a thread cut in the breech piece, and is worked backwards or forwards by a lever, so as to release or press home the vent piece. The breech screw is made hollow, so as to allow the charge to be passed through it in loading the gun.

25. In loading at the breech, the projectile first and then the cartridge are inserted through the breech into their respective chambers; the vent piece is dropped into its place, and the breech is then closed by the breech screw. On the gun being fired, the force of the explosion drives the projectile through the bore, compressing its soft lead coating into the grooves, and so imparting to it the rotating motion due to the twist of the grooves.

The heaviest Armstrong B. L. Gun made was the 7″ gun (originally termed 110-Pr.) of 82 cwt. Owing to the small charge of powder used, the muzzle velocities of their projectiles are only about 1,100 to 1,150 feet per second.

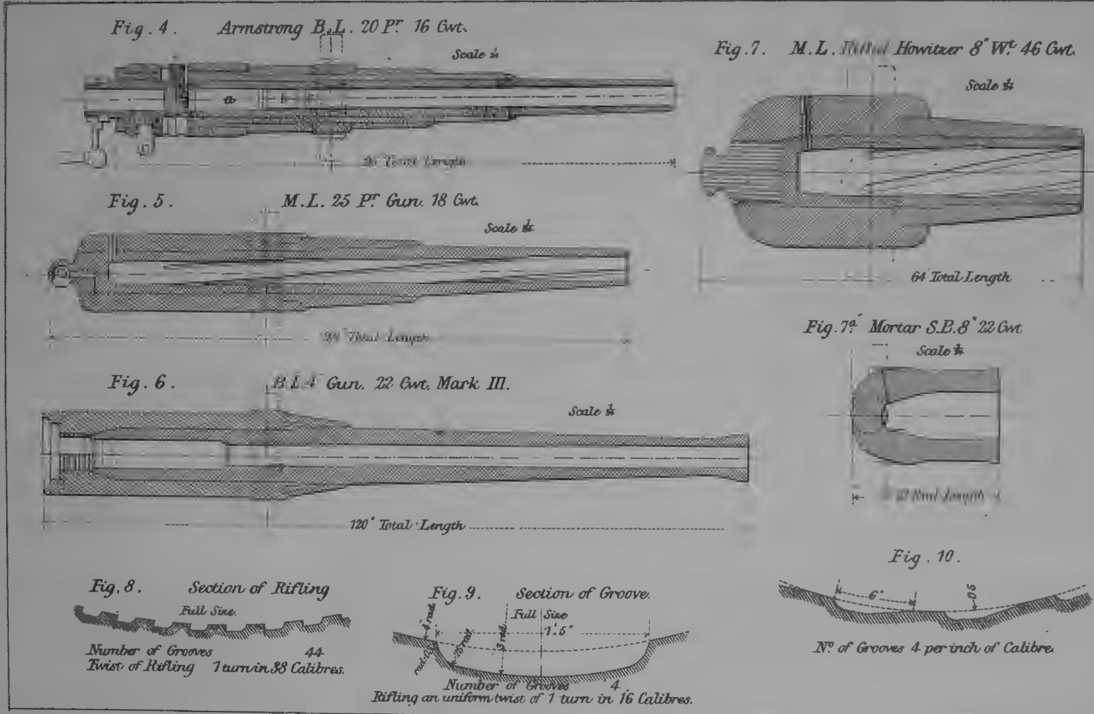
26. *Muzzle-loading Rifled Guns.*—More powerful guns than those of Armstrong being required, especially for service on land against ships, and on ships against ships, the complicated Armstrong System was replaced by the Service M. L. Guns, which are altogether more powerful, and are provided with armour-piercing projectiles.

Fig. 5 represents a section of the 25-Pr. M. L. Gun of 22 cwt., and Fig. 7 is a section of an 8″ M. L. Rifled Howitzer of 46 cwt., a very short piece of Ordnance, specially useful at sieges, and generally in positions in which short ranges only are required, while a heavy shell carrying a large bursting charge can be employed.

27. The general mode of construction is as follows:—The bore is composed of a *solid-ended* steel tube, which has been forged from a cast ingot, bored out, and toughened by being plunged, when heated to a high temperature, into oil. It thus parts slowly with its heat (oil not boiling under 600° F.), and is toughened as well as hardened.

The remainder of the body of the gun is built up of *double* or *triple coils* shrunk on to the steel tube, or on to one another.

TYPES OF RIFLED ORDNANCE.



28. A *coil* is made by heating a long bar of wrought iron and twisting it round a mandril, so as to form a rough cylinder, which is then welded, turned and bored to the required dimensions. The cylinders thus made from the coils are in short lengths (about 3 feet); any increase in length is made by welding two or more coils together.

A *double* coil is made by winding a bar of wrought iron over one previously coiled in the reverse direction, and then welding and preparing the mass as a single coil. The breech is closed in the larger calibres by a *cascable* screw, which is a solid block of forged wrought iron, screwed into the breech coil until it presses against the end of the steel tube. In the smaller calibres, the A (bore) tube is carried through to form the cascable.

29. The rifling of M. L. Guns consists of a number of broad and shallow grooves, varying from 3 to 10 according to the calibre, of the shape shown in Fig. 9. The projectile is smaller than the bore, and has projecting studs of soft metal on its exterior, which on loading fit loosely in the grooves. In loading a rifled gun from the muzzle, the studs of the projectile on passing down the bore press against one side of the grooves, termed the *loading* side; but on passing out of the bore, they press against the other side, termed the *driving* side, and thus impart to the projectile the rotatory motion due to the twist of the grooves. The studs fit loosely in the grooves, both in loading and firing, but owing to their pressing against one side when fired, the projectile is centred, that is, it moves along the bore with its axis coinciding with that of the gun.

30. Recently, *studless* projectiles have been provided for M. L. Guns: the use of *gas checks*, referred to hereafter, having done away with the necessity for studs. Studded projectiles for M. L. Guns are not, however, abolished.

The muzzle-loading guns have been made of all calibres up to the 16″ M. L. Gun of 80 tons, and the 17·72″ M. L. Gun of 100 tons. They are all powerful guns, capable of withstanding the effects of charges of powder sufficient to impart a muzzle velocity of from 1,400 to 1,500 feet per second to their projectiles, and those of 7″ calibre and upwards are armour-piercing guns, provided with special battering projectiles.

31. *Present Breech-loading Guns.*—Since the introduction of M. L. Guns (about 1870), there has been a constant demand for guns more and more powerful, in order to be able to cope with ironclad ships, which have been constantly increasing in thickness of armour.

Increase of velocity to the projectile is acknowledged to be the best form in which increase of power in a gun can be given: the present B. L. Guns are strong enough to withstand charges of powder sufficient to give a muzzle velocity of *over* 2,000 *feet per second* to their projectiles. For list of actual charges used, see Table of Rifled Ordnance, p. 11.

In order to reduce to a minimum the stress on the gun with the large charges of powder requisite to develop high muzzle velocities, a slow-burning powder (see Art. Gunpowder) is used with recent heavy guns; and to enable the fullest possible effect to be obtained from the charge, the guns are now made much longer than formerly. This increase of length (see Fig. 6) is one principal feature in the new type of gun.

Another peculiarity is the enlargement of the bore to form a *chamber* for the receipt of the cartridge: the diameter of the chamber is about one-third more than that of the bore.

32. The object of a chamber is to enable a short cartridge to be used, and to allow a given charge of powder to be fired in a given space, larger than is actually occupied by the powder. This is termed "air spacing," and the effect of it is to allow of the use of a heavier charge, and to obtain thereby a higher muzzle velocity without unduly increasing the strain on the gun. On an average the capacity of the chambers of B. L. Guns is about 40 per cent. in addition to what would be actually required by the charge itself.

The combined effects of a long gun, an enlarged chamber, and a heavy charge of slow-burning powder, are very high muzzle velocities (2,000 f.s. and upwards), with a strain on the gun less than is given to the original M. L. Guns, which have velocities of only from 1,400 to 1,500 f.s.

33. As regards the comparative advantages of muzzle and breech loaders, opinions differ considerably; but there is no doubt that a muzzle-loading gun is a more simple weapon than a brecch-loader; but the great length of modern guns has made the re-adoption of the breech-loading system a matter of necessity rather than choice, at least for heavy guns. It has been stated officially in Parliament that: "High velocity is now required for the projectile, and this can only be obtained by length of gun; and a gun beyond the usual length cannot be loaded at the muzzle under ordinary circumstances." And this statement applies as much to heavy guns in casemates of shore batteries as to those on ships.

34. The system of rifling with B. L. Guns is as follows:—The gun is provided with numerous shallow, rounded grooves of the type shown in Fig. 10. Any groove in a gun is now recognized as a source of weakness, and therefore an evil, although a necessary one. This evil is reduced to a minimum by having the grooves as above, instead of their being few in number, deep, and sharp-cornered.

The size of groove is similar for each gun; their number increases with the calibre, being usually at the rate of 4 grooves per inch of calibre—*i.e.*, the 6" B. L. Gun has 24 grooves.

The twist given to the grooves is an increasing twist from the breech, where it starts at the rate of about 1 turn in 110 or 120 calibres to 1 turn in 35 calibres, at a distance of about 10 calibres from the muzzle: the remainder being a uniform twist of 1 turn in 35 calibres.

The "increasing" twist adopted gives rotation to the projectile *gradually* and *not suddenly*, with nearly uniform pressure on the grooves; and it facilitates high velocities, without undue stress on the gun.

35. The breech is closed on the "interrupted screw" principle, and is as follows (see Fig. 6):—

The cylindrical chamber is fully open to the rear, to permit the insertion of a cartridge of the diameter required.

The *breech screw*, or *breech block*, has on its exterior three longitudinal smooth surfaces (each one-sixth of the circumference), which *interrupt* the screw which is cut on the remainder of the surface, and is left in relief. The exterior of the breech screw is thus divided into six equal portions, which are occupied alternately by the threads of the screw and by the smooth surfaces.

The breech of the gun is prepared in a similar manner. Thus the raised portion of the thread of the breech screw, coming opposite the relieved portion of the thread in the gun, can be readily pushed home; and a turn one-sixth of the circumference suffices to engage the threads and securely close the breech.

When the breech screw is withdrawn it is received on to a *carrier*, which revolves to the right on a hinge, and thus moves clear of the bore and permits the gun to be loaded.

36. Projectiles for B. L. Guns are provided with a *gas check*, or *driving ring*, formed by a narrow band of copper sunk in a groove near their base, and projecting slightly from their surface, sufficiently to make the diameter of the band a little more than that of the bore of the gun. On being fired this copper band is compressed into the grooves, and imparts the necessary rotation to the projectile, which it *centres*, while it also does away with windage, and thus causes the full effect of the charge to be expended on the projectile.

37. *Construction of B. L. Guns.*—In all B. L. Guns the bore is turned in a solid block of tough steel (A tube), and the requisite increase of strength to the gun near the breech is obtained by "*shrinking on*" coils of wrought iron, or, as in the most recent patterns, rings or *jackets* of tough steel. The latest guns, therefore, are made entirely of steel. Fig. 6 is an example.

Nature and Mark.	Service.	Weight.	Calibre.	Length.	Rifling. Number of Grooves.	Rifling. Twist in Calibres.	Charge. Battering.	Charge. Full.	Shell, Studless. Weight in lbs. Common.	Palliser.	Shrapnel.	Bursting Charge. Common.	Bursting Charge. Palliser.	Case Shot.	Muzzle Velocity.	Perforation of Wrought Iron. At Muzzle.	At 1000 Yards.	Range.	Range.	Range.
		tons cwt	in.	ft. in.			lb.	lb.				lb. oz.	lb. oz.	lb.	f.	in.	in.	yds.	yds.	yds.
Recent Breech-loading Guns. B. L.																				
16·25-in. Armstrong	S. S.	110 —	16·25	43 8	—	Not yet completed.	900	—	—	1800	—	—	—	—	2020	32·5	30·5	—	—	—
15-in. wire R. G. F.	"	63 —	15	42 7·2	—	"	880	—	—	1700	—	—	—	—	210	34·5	32·5	—	—	—
13·5-in.	"	63 —	13·5	36 1	—	"	625	—	—	1250	—	—	—	—	205	30·6	28·6	—	—	—
12-in. Mark VI. ..	"	46 —	12	35 1·5	—	"	450	—	850	850	—	24 12	6 4	—	2100	27·5	25·6	—	—	—
10 "	L. S.	26 —	10	28 6	—	"	300	—	500	500	—	17 8	—	—	2100	23·1	21·1	—	—	—
9·2 "	S. S.	19 —	9·2	25 10	37	I. 1 in 120 to 1 in 30	170	—	380	880	—	15 8	3 12	—	2050	20·6	18·6	—	—	—
8 " Mark IV. ..	"	13 —	8	21 2·5	32	" 1 in 120 to 1 in 35	100	—	210	210	210	12 7	2 2	—	2030	16·3	14·1	1° 1632	7° 6184	—
7 "	"	10 —	7	22 8·5	—	Not settled.	100	—	160	160	—	—	—	—	2250	17	14·75	—	—	—
6 " Mark III. ..	"	— 89	6	14 2·7	24	I. 1 in 120 to 1 in 35	42	21	100	100	—	6 6	1 3	—	1880	11·9	10	1° 1450	7° 54′ 5600	13° 48′ 8000
5 " " II. ..	"	— 36	5	11 7·5	20	" 1 in 120 to 1 in 25	—	16	50	—	—	3 5	—	—	1800	8·7	6·7	1° 5′ 1200	7° 56′ 4900	10° 59′ 6000
4 " " III. ..	"	— 22	4	10 —	16	" 1 in 120 to 1 in 30	—	12	25	—	—	1 5	—	—	1900	7·7	5·7	1° 3′ 1200	8° 2′ 4600	10° 56′ 5500
22-Pr.	Field L. S.	— 12	3·5	8 11·5	14	" 1 in 120 to 1 in 28	—	7·5	22	—	—	1 4	—	22	1785	6·7	5·2	—	9° 4856	—
12 "	"	— 7	3	7 8·3	12	" 1 in 120 to 1 in 28	—	4	12·5	—	—	0 7½	—	—	1705	5·3	3·7	1° 1124	9° 4073	—
M. L.																				
10·4-in.	L. S.	25 —	10·4	23 9·4	21	" 1 in 200 to 1 in 40	190	—	464	464	—	17 4	4 2	—	1810	18·6	16·8	1° 1458	5° 4494	—
Muzzle-loading Guns, Principal Types of.																				
17·72-in. Mark I.	L.	100 —	17·72	32 7	28	" 1 in 150 to 1 in 50	450	337½	1922	1968	1995	78 0	32 0	2000	1548	24·8	22·8	—	—	—
16-in. " I.	L. & S.	80 —	16	26 9	33	" 0 to 1 in 50	450	337½	1640	1684	1696	60 0	16 0	1720	1604	25·3	23·3	—	—	—
12·5-in. " II.	"	38 —	12·5	19 2	9	" 1 in 438 to 1 in 35	210	157½	785	809·6	815·9	33 0	8 10	805	1546	19	17·1	—	—	—
11 " " II.	"	25 —	11	15 0	9	" 0 to 1 in 35	85	60	526	543·2	532	22 0	4 14	200	1315	15·4	13·4	1° 400	8° 2515	—
10 " " II.	"	18 —	10	15 0	7	" 1 in 100 to 1 in 40	70	44	390·7	406	408	19 9	4 0	143	1364	14·2	12·2	490	3100	—
9 " " V.	"	12 —	9	13 0	6	" 0 to 1 in 45	50	33	241·8	253·5	254	14 8	2 10	107	1420	12·2	10·2	500	3350	—
8 " " III.	•S.	9 —	8	12 0	4	" 0 to 1 in 40	35	21	166	175	179	15 0	—	74	1413	10·3	8·3	520	3200	—
7 " " IV.	L.	7 —	7	12 4	3	U. 1 in 35	30	17	106·14	112	116	9 4	—	68	1540	—	7·2	550	3250	—
64-Pr. " III.	L. & S.	— 04	6·3	9 10	3	" 1 in 40	12	10	57·6	88	66	7 0	—	50	1383	—	—	600	3320	—
40 " " II.	L.	— 35	4·75	10 0	3	" 1 in 35	—	7	37·8	—	42·12	2 8	—	38½	1380	—	—	—	—	—
25 " " I.	"	— 18	4	8 2	3	" 1 in 35	—	4	23·4	—	25	1 12	—	24¼	1320	—	—	—	—	—
16 " " I.	"	— 12	3·6	6 6	3	" 1 in 30	—	3	15	—	17·13	1 2	—	15¼	1355	—	—	—	—	—
13 " " I.	"	— 8	3	7 8	10	I. 1 in 100 to 1 in 30	—	3½	12·6	—	12·15	0 10	—	13½	1560	—	—	—	—	—
9 " " II.	L. & S.	— 8	3	6 0	3	U. 1 in 30	—	1¾	8·9½	—	—	—	—	9¾	1380	—	—	—	—	—
7 " in 2 parts ..	L.	400 lbs	2·5	5 10½	8	I. 1 in 80 to 1 in 30	—	1½	6·12	—	6·15	0 4	—	6¾	1440	—	—	—	—	—
7 " Mark IV.	L. & S.	200 "	3	3 5	3	U. 1 in 20	—	¾	6·14	—	7·10	—	—	6¼	968	—	—	—	—	—

PROJECTILES OF RIFLED ORDNANCE.

38. The projectiles of Rifled Ordnance (omitting exceptional ones) are four in number, viz.:—

Common Shells	Figs. 11 to 14, Plate II.
Palliser, or *Battering Shells*	
Shrapnel Shells	
Case Shot...	

The rotation to shells of all kinds is given as before stated—(1) In the case of Armstrong Guns, by the lead coating of the projectiles; (2) In M. L. Guns, either (a) by the studs or (b) by the *gas checks;* and (3) In the B. L. Guns, by the *gas check* (or *driving ring*) only.

39. *Common Shells* (Fig. 11).—Common Shells are hollow cylindrical cast iron projectiles, the interior being filled with the *bursting charge* of powder. The head is conoidal, and provided with an opening (*fuze hole*) for the insertion of a fuze.

When fired, the shell ,is burst at the required moment by the action of the *fuze*, and the destructive effect is due to the large bursting charge carried, which causes the splinters to fly with extreme violence: the bursting of the shell is also a *most violent* explosion.

Common Shells are used either to do damage by their splinters, as when fired against troops in masses; or to destroy earthworks, buildings, wooden ships, &c., by first penetrating them, and afterwards exploding in them. In the former case they should burst a little before they reach the object; in the latter, just after reaching it. Under suitable conditions Common Shells are terribly destructive; against troops in extended order Shrapnel Shells are, however, more efficient.

40. A *Double Shell* is a shell of increased length (4 calibres), so as to hold a larger bursting charge. It is issued only to a few guns, and is intended for short ranges with reduced charges of powder.

41. *Palliser*, or *Battering Shells* (Fig. 12).—These are the projectiles specially intended for penetrating the armour-plates either of ships or of sea defences. An ordinary mass of cast iron fired against iron armour breaks to pieces without effecting penetration, to secure which special conditions are required to be combined. These conditions are principally (a) hardness of metal to the head of the projectile, and (b) suitable shape. Both of these are fulfilled in the Service battering projectiles.

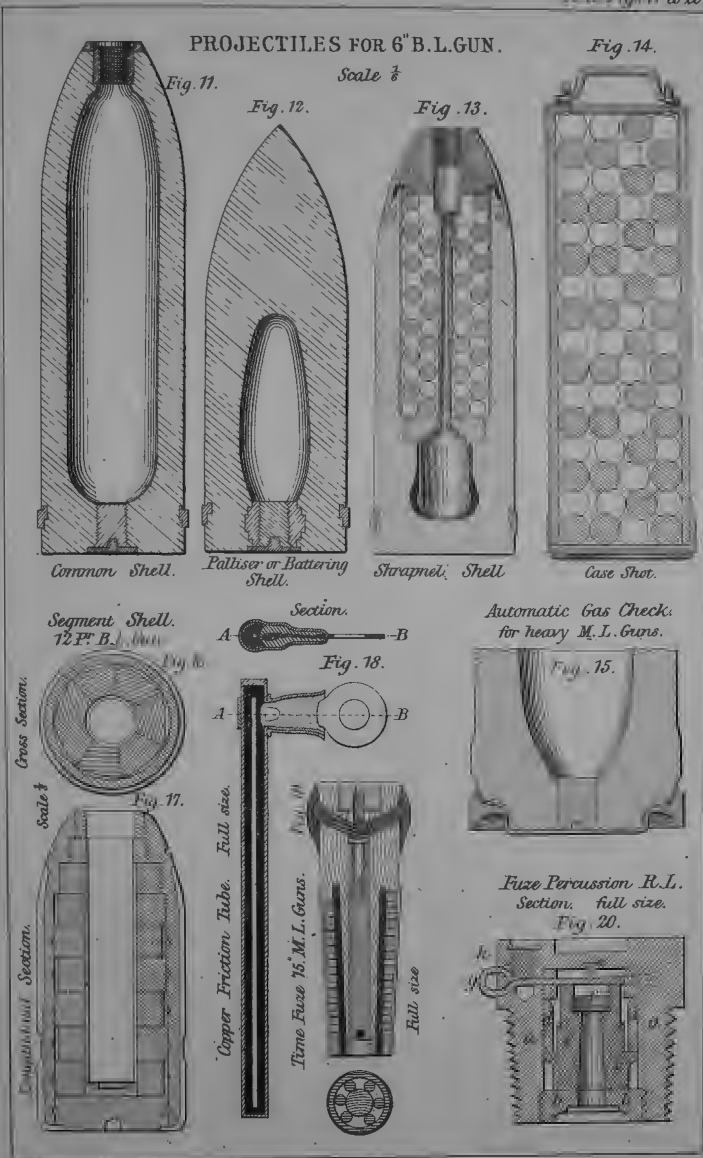
The shell is of cast iron, having an ogivale head, the radius of the curve for which is about 2 calibres; this gives a sharp point to the head. The fore part of the shell is cast in an iron mould, by which that part becomes rapidly cooled, or "*chilled*," and made intensely hard. That portion of the mould which takes the body of the shell is of sand, by which the base of the shell is unhardened, so as to avoid exposing too brittle a portion to the shock of discharge.

These shells are thicker than Common Shells, and their bursting charge is much less. The interior is filled with powder.

42. The shell, on striking a suitable object, such as an armour-plate, penetrates and bursts immediately, *without any fuze being required.*

The cause for this particular action was originally attributed to the heat generated in the projectile by its alteration of shape on impact; it is now considered to be caused by the heat generated in the bursting charge itself, by its friction with the interior of the shell-head on impact. When fired the bursting charge is *set back*, and rests at the base of the projectile. When the latter strikes it is suddenly arrested, and the powder inside moves forward towards the head with the velocity of the shell at the moment of striking, and is violently forced into the conical space at the head, with the result of being ignited.

43. *Shrapnel Shells* (Fig. 13).—These are intended to bring a shower of small balls on to an object at all ranges except close quarters. The Shrapnel Shell has


PROJECTILES FOR 6" B.L. GUN.
Scale 1/6
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Common Shell.
Palliser or Battering Shell.
Shrapnel Shell
Case Shot.
Segment Shell.
Cross Section.
Scale 1/4
Fig. 17.
Section.
Fig. 18.
Copper Friction Tube. Full size.
Time Fuze 15" M.L. Guns.
Full size
Automatic Gas Check.
for heavy M.L. Guns.
Fig. 15.
Fuze Percussion R.L.
Section. full size.
Fig. 20.

been termed the *man-killing* projectile, and is terribly effective against troops exposed to view.

The shell is of cast iron, having sides so thin that it is only strong enough to bear the shock of discharge: the head is of wood, covered with thin iron. The sides of the shell have six grooves cast in them, so as to weaken them and enable a *very small* bursting charge to crack open the shell, without violently bursting it, and so release the bullets.

The bursting charge is placed in the space at the base of the projectile, from which an iron tube in the axis of the shell leads to the fuze at its head.

The balls are packed round this hollow axis, the interstices between them being filled with resin.

The effect of a Shrapnel Shell, if burst open at the proper moment (which should be when it is about 80 or 100 yards from the object), is due to the remaining velocity of the shell, and not to the bursting charge. The bullets when released open outwards in what is termed the *cone of dispersion*, and fall in a shower. The bursting charge is intended only to crack open the shell with the least possible violence: if burst at rest the fragments of a Shrapnel Shell only fly a *few feet*, while those of a Common Shell burst at rest will fly from 600 to 1,000 yards.

More nicety is required in firing Shrapnel Shells than with any other projectile, for it is essential that correctness of aim and proper length of fuze be combined in order to obtain the desired result.

44. *Case Shot* (Fig. 14).—This is simply a case or canister of thin sheet iron filled with iron balls. When fired the case breaks to pieces, and the balls are forced to the front over a "cone of dispersion." Being small, the balls soon lose their velocity. For this reason Case Shot for field guns are only used for distances up to 300 yards; if the ground be hard and smooth they are effective for a greater distance. It is the projectile to use at close quarters, when it is, of course, most destructive to troops.

In the example given in Fig. 14 there is an iron disc at the bottom of the case, and a lining formed of three curved iron segments, which serve to protect the grooves of the gun from friction with the shot, which would injure them.

The handle shown is for convenience in loading.

The bullets are packed in a mixture of sand and clay.

45. Special Armstrong Projectile.

The Segment Shell (Figs. 16, 17, Plate II.) consists of a thin cast iron shell, inside which are placed a number of rows of cast iron segments, which form a series of rings round the central cavity that contains the bursting charge. The interstices between the segments are filled with lead. The *lead coating* of the projectile is shown also in the figures. The interior surface and the head of the shell are provided with grooves to cause it to burst easily. The bottom of the shell is a separate casting, and is pressed in after the segments have been inserted.

This shell is, from its construction, very strong to resist an external or crushing pressure, such as acts on it when forced through the grooves of the gun, but very weak to resist a bursting pressure from inside, and therefore it requires but a small bursting charge to break it open.

46. When the shell is burst, the segments fly outwards, owing to the centrifugal force due to the rotation of the shell, at the same time that they are carried forward by its onward velocity at the moment of bursting: they thus open out in a cone of dispersion, and produce an effect somewhat similar to that of a Shrapnel Shell in bringing a shower of pieces of metal on to an object.

Segment Shells should be burst close in front of an object. The lower natures of Segment Shell are usually fired with both a time and a percussion fuze: the time fuze is screwed in the fuze hole, with the percussion inside, so that should the time fuze fail to act the shell is burst on ricochet by the action of the percussion fuze.

Segment Shells have been used only with Armstrong B. L. Guns.

47. Gas Checks.

The original use of a gas check was, as its name implies, to prevent the escape of gas through the windage when a M. L. Gun was fired. This escape was found seriously to erode the bore of heavy guns, more especially over the seat of the shot, and to render them consequently short-lived.

The early patterns of gas check consisted of a copper disc, of the same diameter as the projectile, to the base of which it was attached with a nut and screw. Some patterns of gas check were flanged, others were saucer-shaped. In either case the soft metal (copper) of the gas check was, on the gun being fired, flattened and opened out by the pressure of the powder gas, which forced it into the grooves and against the lands of the gun, thereby sealing the windage, and attaining the object required.

It having been found that attached gas checks gave good shooting, and themselves imparted rotation to projectiles, this latter fact obviating the necessity of studs being continued in use with M. L. Projectiles, the latest patterns of these are *studless* and provided with automatic gas checks, which serve the double purpose of sealing the windage and imparting rotation to the projectile.

48. Fig. 15, Plate II., is a type of the automatic gas check for heavy M. L. Rifle Guns.

The curved portion of the base of the shell is cast with radial and other grooves, into which the gas check is forced on discharge. The gas checks are made of copper, with projections round the circumference corresponding with the rifling grooves of the gun. They are automatic and are inserted loose in the bore (care being taken to place them in the proper direction for fitting on the shell); on firing they become attached to the shell as described above.

The *driving rings* of present B. L. Projectiles (Figs. 11—13, Plate II.), already described, both close the windage of the gun and impart the necessary rotation to the projectile.

49. *Tubes.*—Guns are fired by means of tubes, which for land service are made of copper. The principal pattern used is the Service short tube, which is thus made (see Fig. 18, Plate II.) It consists of a copper tube, 3″ long, driven with mealed powder, and pierced with a central hole, without which the tube would not explode, but only burn rapidly.

Across the top of the tube is inserted a *nib-piece*, or short cylinder of sheet copper. This nib-piece contains a copper *friction bar*, roughened on both sides, and covered with a detonating composition.

The nib-piece is pinched down so as to press on the sides of the friction bar, the projecting part of which has a vertical eye, into which the hook of the lanyard fits.

On pulling the lanyard (which should be stretched and then sharply pulled), the friction bar is drawn out, igniting the composition and firing the tube.

The gas from the exploded cartridge drives the tube out of the vent.

50. *Fuzes.*—Fuzes are used with shells of all sorts (except Palliser, or Battering Shells) for the purpose of igniting the bursting charge, and so bursting the shell at the required moment. There are many varieties of fuzes in use, but they may be divided into two classes—viz., *Time Fuzes* and *Percussion Fuzes*, in the former of which there is a composition, which, being set fire to by the discharge of the gun, burns at a regular and known rate, and is made to ignite the bursting charge in a given *time* (according to the time of flight of the shell) after the shell leaves the gun; in the latter, the shock experienced by the shell on impact causes a patch of detonating composition in the fuze to be ignited, the flame from which is led to the bursting charge of the shell. But in order to avoid accidental explosions, this detonating arrangement cannot act unless set free to do so by the effect of the shock of discharge.

One type of each of the two classes is here given:—

51. *The* 15 *Seconds M. L. Fuze, Time* (Fig. 19, Plate II.)—This time fuze is of wood, tapering slightly, so as to fit easily into the fuze hole. In the centre is the *composition channel*, which extends nearly to the bottom, and is driven with 2″ of a composition which burns at the rate of 1 inch in $7\frac{1}{2}$ seconds. Above this is a pellet of mealed powder, having a hole bored down it for about two-thirds of its depth. The head of the fuze is closed by a gun-metal plug, round the pin of which quickmatch is looped, and led through two fire holes to a groove on the outside of the head of the shell.

There are six *powder channels*, filled with fine powder, and which all extend through the bottom of the fuze. A paper scale pasted on the outside of the fuze gives the length of composition (opposite one or other of the powder channels) for each quarter second of burning. To prepare this fuze, a small hole is bored from the exterior through a powder channel into the composition channel at the intended point, which depends on the time of flight; the fuze is then fixed in the fuze hole of the shell, and the latter loaded in the gun.

52. The flash of discharge ignites the fuze composition by means of the quickmatch at the head, and when the composition has burnt as far as the bored hole, it sets fire to the powder in the powder channel, the flash of which strikes downwards into the shell.

Although six powder channels are made in this pattern of fuze, only one of them is made use of, according to the actual time of flight of the shell for the range required.

The 15″ fuze can be used for all ranges up to 15 seconds time of flight.

Fuzes for Mortars, which have long times of flight, do not require powder channels, as the bored hole referred to above comes, when the fuze is placed in the shell, inside the shell, and not opposite the metal thereof. When the fuze composition has burnt down to the bored hole, the flame can escape at once into the shell through the bored hole, and so ignite the bursting charge.

53. *Fuze, Percussion R. L.* (Fig. 20, Plate II.).—This is the percussion fuze chiefly used in field service, and is therefore described. It, as well as other percussion fuzes, is made of gun-metal, slightly conical, and tapped externally with a screw to fit into the fuze hole.

In the bottom of the fuze is screwed a *bottom plug* of gun-metal, and on the top, from the lower surface of the head, a *steel needle* projects inwards.

Inside the body is a gun-metal *guard*, raised as shown in the figure, and supported in position by two "feathers" on the exterior circumference of a *pellet* made of lead and tin in equal proportions.

There is a bevelled edge on the pellet above the feathers, corresponding to a similar recess in the interior surface of the guard (see section in plate).

The pellet is hollow, and cupped out at the top to receive a *copper cap*, containing percussion cap composition.

The safety of the fuze in transit, &c., is insured by a *safety pin* of twisted brass wire, to which is attached twine, wherewith to pull it out at the moment of loading.

The safety pin passes through one side of the head, through the space between the pellet and the head, and through the guard into the other side of the head, where the wire ends are opened out. In order to close the aperture left by the withdrawal of the safety pin from the flash of discharge, a small *lead pellet* slides freely in a recess, and when the shell is rammed home it sets back, and so closes the safety pin hole.

54. The action of the fuze is as follows:—On the shock of discharge the guard sets back, shearing off the two feathers of the pellet, and locks itself on to the pellet by means of the projection on the latter wedging into the undercut recess in the guard.

On impact (or graze) the pellet and guard fly forward, and drive the cap against the steel needle, thus igniting the detonating composition, the flash from which passes downwards into the shell.

55. *S. B. Ordnance retained in the Service.*—A Mortar (Fig. 7*a*, Plate I.) is a very short piece of Ordnance, having the trunnions at the end, intended to throw shells at high angles of elevation, usually 45°. The mortar rests on a *mortar bed* (Fig. 26, Plate III.). The elevation being, as a rule, constant, the charge of powder has to be varied for particular ranges. For each calibre of Mortar, tables of charges are prepared for each 100 (or 50) yards of range.

Many large Mortars are still mounted in fortresses, and are likely to remain for many years. They are very useful for dropping shells into a confined space, such as a fort or bastion, but are not able to hit a particular object, such as a single gun. Mortar shells, which drop from a great height, are capable of breaking through insufficiently protected powder magazines, and searching out the weak buildings of a place generally. Their fuzes should be a little *long*, so as to burst immediately after, but not before, striking an object.

56. *S. B. Guns retained.*—The 32-Pr. S. B. Gun of 42 cwt., large numbers of which are on hand, is being converted from a M. L. into a B. L. Gun, for the purpose of being used in the flanking parts of forts as a gun for the rapid firing of case shot only.

For this particular purpose a rifled gun is not necessary; in fact, a smooth bore is preferable for firing case shot. The gun will be mounted on a carriage specially made to check recoil.

The breech-loading arrangement (interrupted screw, similar to that described in Art. 35) is specially advantageous in caponiers in which these guns will be mounted.

Rockets.

57. *A Rocket* consists of a cylindrical case of paper or metal, containing inflammable composition; to one end of the case is attached a head, usually of a conical or cylindro-conoidal form; the other end is closed, but has one or more vents or holes in it, for the escape of the gas of the ignited composition.

There is a conical hollow space in the interior of the rocket, extending nearly throughout the length of the composition. The object of this hollow in the interior of the rocket is, that a large surface of composition may be at once ignited, and the gas be thereby generated more quickly than it can escape through the vents; the result is, that the gas becomes condensed inside the rocket, and exerts a pressure in every direction on the interior surface.

The pressures on the sides of the rocket neutralize one another, but the pressure on the head exceeds that on the base, in consequence of the escape of the gas from the vents. This excess of pressure on the head over that on the base causes the rocket to move in the direction of the head, slowly at first, but with an accelerating motion, owing to the continued generation of fresh gas, and its escape through the vents, which increases until the resistance of the air is equal to the force of progression, or until the composition is consumed.

The motion of a rocket is in reality a continued recoil, differing from that of a gun in being caused by a continuous force which acts during a great part of its flight; whereas the recoil of a gun is caused by an impulsive force, which ceases to act on it as soon as the projectile has left the bore.

A stick or long rod is attached to the base or side of the rocket, to guide it in its flight.

There are two descriptions of rockets used in the Service—viz., the Signal Rocket, and the Hale Rocket. The former are used as signals at night, and the latter as destructive projectiles.

58. The Signal Rocket has its case and head of paper; the latter contains the composition for the stars; the bottom of the case is choked, so as to form a single vent in the axis; the stick is attached to the side of the rocket case. There are two sizes of Signal Rockets in use—viz., the 1 lb. and the ½ lb. rocket.

Signal Rockets are fired vertically or nearly so. When the composition is consumed, the bursting charge explodes the head and ignites the stars, which in falling produce a brilliant light that can be seen from a considerable distance.

Rockets between 1″ and 2″ in diameter ascend between 450 and 600 yards in height, and are visible within a circuit of from 35 to 40 miles.

59. The *Hale Rockets* (Figs. 21—24) have the composition in a metal case; the head is of cast iron, and has a hollow, which is plugged with wood. The case has three corrugations, as shown in Fig. 24, in order to give the case a firm hold of the composition.

Hale Rockets are contrived so that the gas issuing from the vents imparts a rotatory motion to them, in addition to the forward motion which impels them onwards. They thus acquire a motion similar to that of the projectile of a rifled gun,

FIG. 21.

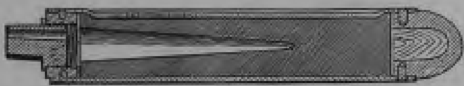


FIG. 22.

FIG. 23.—Base.

FIG. 24.—Section at A B.

and do not require sticks to guide them in their flight. The gas on issuing from the vents presses on the metal projections, termed *half shields*, which are slightly oblique to the axis, and causes the desired rotation.

Two natures of this rocket are in use, the 9-pr. for field service, and the 24-pr. for fortresses.

It is probable that the plugged head will be altered to a shell with a bursting charge, in order to increase the destructive effect.

Troughs are supplied to fire the rockets from. They are provided with a suitable arrangement for giving the required elevation. They may also be fired from the ground, the head of the rocket being slightly elevated. A number of rockets placed in a row, and fired in this manner, may be used with effect against cavalry.

60. Rockets are employed, both in the land and sea services, to set fire to houses, shipping, &c., in the bombardment of towns, in addition to their being used simply as projectiles.

Rockets have the advantage of containing within themselves their own propelling power, and they may therefore be used in many situations where it would be impracticable to transport artillery, or in which they can be brought into action sooner than artillery, as, for instance, on first landing on an enemy's shore. They, however, have the defect of being very irregular in their flight.

Carriages for Ordnance.

61. The Carriages on which Ordnance are mounted are divided into two general classes—the one including all those upon which the gun travels, or is conveyed, as well as worked in action; the other comprising all carriages upon which ordnance is mounted when placed in permanent or fixed positions, but which are not intended to be used in their transport.

To the former class belong *Field* and *Siege Artillery Carriages;* to the latter, *Garrison* and *Ship Gun Carriages, Traversing Platforms, Moncrieff* (or *Disappearing*) *Carriages*, and *Mortar Beds. Types* of each class are given in Plate III. and Plate IV.

62. Fig. 25 represents in side view a Standing Garrison Gun Carriage for a 64-Pr. M. L. Gun, which when thus mounted can fire over a height of $2\frac{1}{4}'$. The carriage is of wood; the trucks are of cast iron.

Fig. 26 represents a Mortar Bed for a 10″ Mortar. Mortar beds are made of cast iron.

When the bed rests on a level surface (such as a *Mortar platform*) the Mortar has an elevation of 45°.

63. Fig. 27 represents a heavy gun on a Casemate Traversing Platform.

The traversing platform is of wrought iron, provided with trucks, and moves horizontally, or *traverses*, on iron rails or *racers*, in an arc of a circle having any convenient point as a centre.

The carriage, also of wrought iron (double plate), is somewhat similar to a garrison carriage without trucks. It slides along the sides of the traversing platform (which rise to the rear at a slope of 5° to check recoil), and its recoil is stopped at the rear of the platform by various kinds of *buffers*.

By this arrangement the heaviest guns in use can be worked easily and quickly by a few men. The mechanism for large guns is complicated, but the principle followed is the same. In all, the aim horizontally is given by *traversing* the platform, and vertically by *elevating* the gun sufficiently on its carriage. The gun is, of course, run up to the front of the platform before being fired, and recoils to the tail thereof when fired.

64. Fig. 28 represents a gun on a Moncrieff (or Disappearing) Carriage.

This carriage gives the power of loading the gun and approximately aiming it while under cover and quite concealed from view; it is then brought to the firing position and fired over a parapet, the recoil bringing it backwards to a *lower level*, where it disappears from view. There are two patterns of Moncrieff Carriages, that shown in Fig. 28 being the most recent.

The gun rests on an *elevator* (Fig. 28), which *rolls*, but does not recoil, on the *platform*. In rolling, when the gun is fired, the trunnion holes move backwards about 11 feet, and downwards about 6 feet; consequently the gun may be said to recoil 11 feet and to drop 6 feet on being fired.

The elevator contains a *counterweight* a little heavier than the gun.

By the rolling action of the elevator, the gun when fired moves back by the force of its own recoil, from the *firing position* in which it is shown in Fig. 28, to the *loading position* shown by dotted lines.

It is there retained by a *break* until the loading is completed. The gun is then released from the break, the counterweight drops, and the gun rises to the firing position, to disappear again from external view on being fired.

The gun is thus exposed to view only for the short time required to complete the aim.

65. Plate IV. gives examples of the two principal types of travelling carriages. These were formerly made of wood, but now are wholly of iron.

Fig. 30 is a side view of a wrought iron *Field Carriage* for a 13-Pr. M. L. Gun, and Fig. 31 is a side view of the *Limber* for the same.

The gun when in action rests (as in Fig. 30) on three points, viz., the two wheels and the trail.

TYPES OF CAR[illegible]

Side View of a Heavy Gun [illegible]

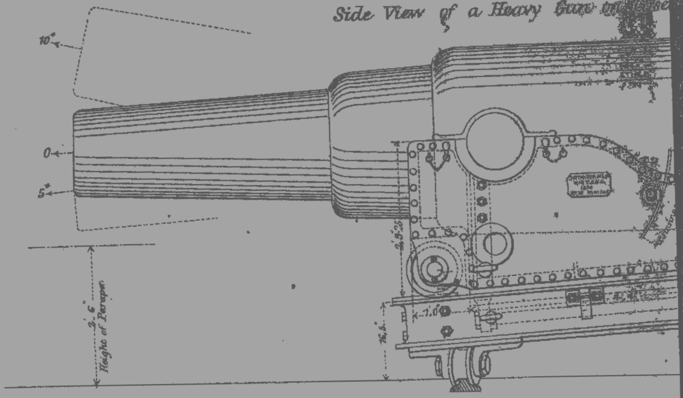
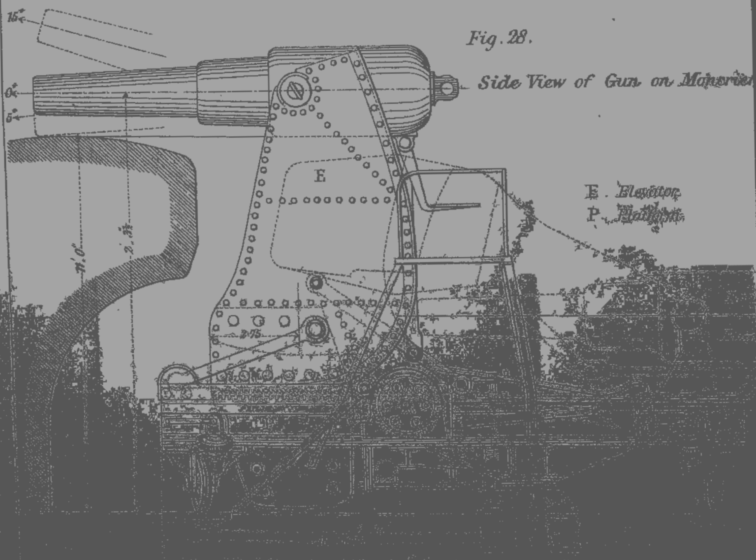


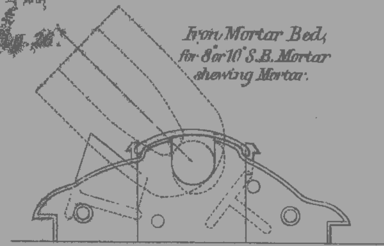
Fig. 28.

Side View of Gun on Moncrie[illegible]

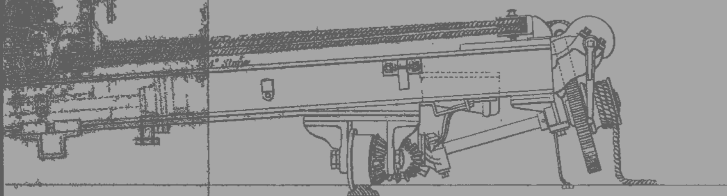


E. Elevator.
P. Platform.

Fig. 26.



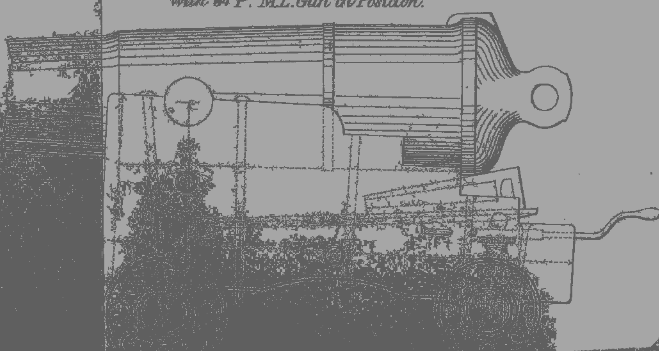
Iron Mortar Bed, for 8" or 10" S.B. Mortar shewing Mortar.



…arriage. Mark II.

Fig. 25.

Side View of Standing Garrison Gun Carriage, with 64 P.r M.L. Gun in Position.



SIEGE GUN CARRIAGE. *(Overbank) for 40 Pr. Gun.*

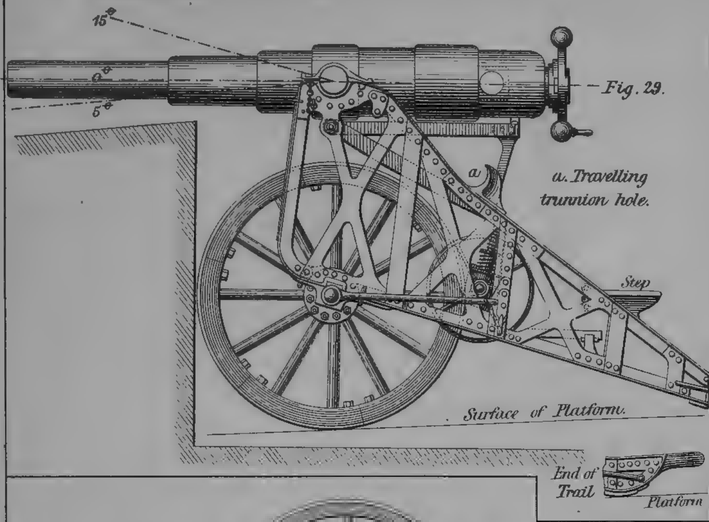


Fig. 29.

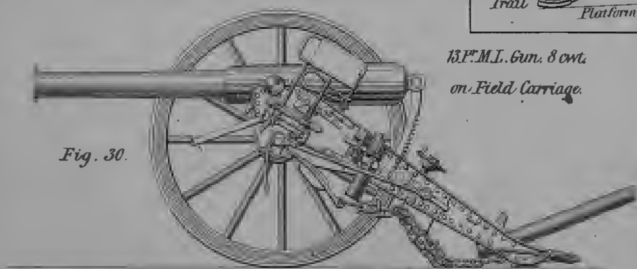


Fig. 30.

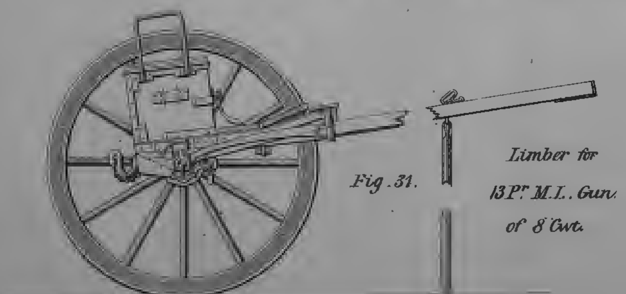


Fig. 31.

When required to be moved, the trail is hooked on to the limber (the gun being then said to be *limbered-up*), and the gun carriage and limber thus become a four-wheeled carriage.

Field guns fire over a height of 3½ feet.

Fig. 29 is a side view of a 40-Pr. Gun, mounted on a siege carriage, adapted for *overbank* fire, which permits the gun to fire 6 feet above the platform surface.

The gun is shown in the *firing trunnion holes.* When required to travel, the gun is moved backwards to the travelling trunnion holes (*a*), so as to distribute its weight fairly between the wheels of the carriage and those of its limber, to which it is secured in a similar manner to that of a field gun.

Various Kinds of Artillery Fire.

66. The fire of artillery may be, as regards the direction and position of the object, either *Frontal, Oblique, Enfilade, Reverse, Flank*, or *Cross;* and as regards the elevation used, it may either be *Direct, Indirect* or *Curved, High Angle*, or *Plunging.*

67. Fire as regards Direction.

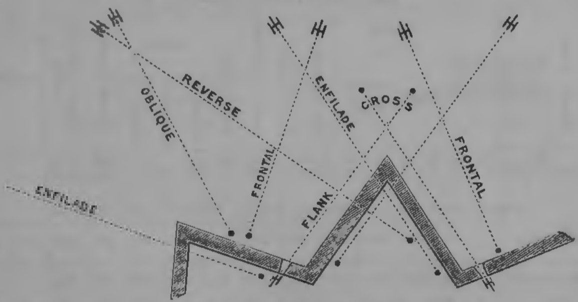


Fig. 32.

Frontal fire is that of which the direction is perpendicular, or nearly so, to the line of the object (whether formed by troops or by a line of fortification) fired at.

Oblique fire is that of which the direction is oblique to the line of the object fired at. No authority is laid down as to the degree of obliquity necessary for the term to apply. The term must be used generally.

Enfilade fire is that which is directed along a line fired at; the gun requires, therefore, to occupy the prolongation of the line to be *enfiladed.*

Reverse fire is that which is brought to bear on the rear of an object, which is then said to be taken in reverse.

Flanking fire is that which *defends* a line by bringing a fire along its front, parallel, or nearly so, to the line defended, or *flanked* by it. It is thus named, because an enemy, when attacking the work, would have his own flank exposed to (or be taken in flank by) the flanking fire.

Cross fire is that obtained by the lines of fire of two or more guns in different positions crossing one another on any particular spot, which is thus doubly protected.

68. Fire as regards Elevation.

Direct fire is that which is obtained from guns with Service charges at all angles of elevation not exceeding 15°.

Indirect or *Curved* fire is that obtained from guns with reduced charges, and from howitzers and mortars with all charges, at all angles of elevation not exceeding 15°.

High Angle fire is that obtained with all charges from guns, howitzers, and mortars, at all angles of elevation exceeding 15°.

Plunging fire is that which can be brought to bear from a gun in a high situation on to the ground, level, or nearly so, below it. If the ground sloped up to the gun the fire would cease to be *plunging*, and would be termed *grazing*.

Plunging fire implies *height of situation* for the gun. Against a moving object, such as an enemy advancing to the attack over open ground, it is the least effective fire, as there is the least margin for error in aim; but against a fixed object, such as an enemy in trenches or batteries at a siege, it is most effective, for the projectile (fired with Service charges) will cut through the crest of the parapet, and search out the ground beyond most thoroughly.

Curved and High Angle fire will equally reach, or search out, objects concealed from view, as well as Plunging fire, which latter can seldom be applied; whereas the two former can be used under all circumstances when it is requisite to give to a projectile a steep angle of descent. The concealed escarps of fortresses would require to be breached by this kind of fire.

69. The Infantry Rifle.

Martini-Henry Rifle.	Diameter of Bore.	Weight of Arm without Bayonet		Length of Arm without Bayonet		Bayonet.				Arm Sighted to.	No. of Grooves.	Twist: one turn in.	Powder Charge.	Bullet.			Initial Velocity.	Weight of 60 Rounds Packet.	Remarks.
						Weight.		Length beyond Muzzle.						Weight.	Diameter.	Length.			
		lb.	oz.	ft.	in.	lb.	oz.	ft.	in.	yards		in.	grs.	grs.			feet.	lb. oz.	
	·45″	8	12½	4	2	1	7	1	10	1400	7	22	85	480	·45	—	1350	6 10	

Terminal Velocities, Martini-Henry Rifles. Service Charge, 85 grains.

Range in Yards ...	0	100	200	300	400	500	600	700	800	900	1000	1100	1200
Velocity in Feet ...	1362	1208	1085	1002	951	906	864	826	791	760	730		

Fig. 33.

70. *The Martini-Henry Rifle* derives its name from the fact that it combines the *Martini* breech mechanism with the *Henry* barrel and rifling.

The barrel is of steel, the calibre is ·45″, the grooves are seven in number, and are polygonal—*i.e.*, the bore has seven sides, which circumscribe a circle, the diameter of which is ·45″. Along each angle of the bore there runs a raised rib, which projects inwards as far as the (imaginary) ·45″ circle, and thus forms each groove into a double one.

The rifling has a twist of one turn in 22 inches.

71. *Cartridges for the Martini-Henry Rifle* (Fig. 33) have a case of thin sheet brass. Into the head of the case is choked the bullet, which is ·45″ in diameter, and has a single cannelure for securing it to the cartridge. The bullet is solid, cylindro-conoidal in form, ·45″ diameter at the base, tapering slightly (to ·439″) towards the head. It is made of lead hardened by tin (12 lead to 1 tin). Between the bullet and the powder charge is a wad of beeswax, with thin cardboard wads in front and in rear.

The base of the cartridge has a percussion cap in the centre. The base rim allows the cartridge case to be withdrawn from the chamber after firing. It is impossible to load the rifle with more than one cartridge at a time.

When fired, the bullet is *set up* by the shock of discharge, and its diameter becomes increased sufficiently to take the grooves of the rifle.

This ammunition is waterproof, and by means of the beeswax wad is self-lubricating.

The powder charge is 85 grains.

72. Penetration of Rifle Bullets.

Description of Target.	Martini-Henry Rifle—Range, 20 yards.		
	Penetration.	Proof.	Remarks.
Parapet—earth	18" to 21"	3 feet	
,, sand	15" to 18"	3 ,,	
Sandbags—filled	8" to 12"	2 bags .	Or 1 bag lengthways.
Gabions—filled	12" to 20"	1 gabion	
Timber, Fir—3" plank	4 planks	6 planks	
,, ,, in baulk	7" to 8"	12"	
,, Oak—in log	3" to 4"	6"	

The Martini-Henry Rifle will fire 25 unaimed, or 12 aimed, shots in a minute.

Its extreme effective range is 3,000 yards, at which distance its penetration is as follows:—

1" Fir Boards, 1½" apart.	Damp Sand.	Dry Earth.	Remarks.
4 boards	9 inches	9½ inches*	*At 2,500 yards.

Any distance less than 300 yards is considered *close* range, requiring but little, if any, change of the rifle sights.

Machine Guns.

73. *Machine Guns* are used for the purpose of bringing a rapid and continuous fire of small projectiles to bear on a given spot. They are so named from the fact that the operations of loading and of firing are performed by working a special mechanism—in the case of the Gatling Gun by means of turning a handle, and with the Nordenfelt Gun by working a lever handle backwards and forwards.

Table of Principal Dimensions of Gatling and Nordenfelt Guns.

Gun.	Calibre.	No. of Barrels.	Nature of Rifling.	No. of Grooves	Twist of Rifling.	Weight of Bullet.	Powder Charge.	Weight of Filled Cartridge.
Gatling......	·45"	10	Henry	7	1 turn in 22"	480 grs. lead	85 grs.	800 grs.
Nordenfelt..	1·00"	4	Henry	11	1 turn in 35"	7½ oz. steel	1·43 oz.	11·21 oz.

74. The *Land Service Gatling Gun* consists of ten rifle barrels (calibre ·45 inch, so as to take the Martini-Henry ammunition) attached to a spindle, and caused to revolve by means of a handle in rear of the breech. The cartridges are contained in a drum (holding 240 cartridges), which is placed over the breech, and they drop through a slot in it, are forced into the barrels, and fired one after another, as the barrels revolve. The rate of firing depends merely on the rapidity with which the handle is turned.

An automatic traversing arrangement is attached to the breech, which gives a slight horizontal motion to the barrels, and thus a lateral spread to the bullets. If not required, the traversing arrangement may be thrown out of gear, so as not to act.

SECTION II.

PRACTICAL GEOMETRY—SCALES—GEOMETRICAL DRAWING.

DRAWING INSTRUMENTS: *compasses, protractor; Marquois Scales and Triangle.* — PROBLEMS IN PLANE GEOMETRY: *bisection of a line and of an angle; construction of perpendiculars; to draw a line parallel to a line; to make an angle equal to one given; division of a line into equal parts; reduction of a rectilinear figure to a triangle of equal area; construction of polygons on a given line, and of tangents to circles.*—SCALES: *method of construction; examples of necessary calculations.*—DIAGONAL SCALES: *table of English and Foreign linear measures.*—MENSURATION: *areas of rectangles, triangles, and trapezoids; parapets and ditches.*—INCLINATIONS *of slopes; method of expressing by fractions.* — GEOMETRICAL DRAWING: *orthographic projections; plan, elevation, section, and profile; construction of a plan, a section, and an elevation.*

77. A knowledge of the elements of geometrical drawing is desirable in the study of Fortification, both for the purpose of comprehending the various drawings by which works and buildings are represented on paper, and also for the purpose of tracing, or marking out on the ground, the necessary details of defensive works.

The drawing instruments in use at the Royal Military College are the following:—

A Pair of Compasses, having a movable leg to admit of a pen- or pencil-leg being substituted for it, so as to allow of circles being drawn in ink or pencil.

A Small Pair of Compasses with a pen-leg, for drawing smaller circles than can be described conveniently by means of the larger compasses. These are called bow-sweeps: they should not be used for circles which require the legs to be opened to a greater angle than about 30°, unless they have double joints, which permit the legs to be bent perpendicularly to the paper.

A Pen-leg and a *Pencil-leg*, to insert in the place of the movable leg of the large compasses.

A Drawing Pen.

An Ivory Protractor, to set off angles, and having on it various useful scales.

78. To set off an angle by means of the protractor (Plate V.):—

Let C A (Fig. 34) be the given straight line, C a point in it, and 40° the angle required to be set off. Place the centre mark on the lower edge of the protractor at the point C, and move the protractor round until the line marked 40° on its radiated edge coincides with C A. Draw the line C D along the edge; D C A is the required angle.

If the point through which the straight line, forming the angle of 40° with the line C A, is to pass, be not in the straight line, as D (Fig. 34), the protractor is placed on the line C A, with the centre point and the mark 40° coinciding with that line, and it is moved along the line C A *in this position* until the edge C D coincides with the point D.

In each of the above operations the required line can be drawn with one adjustment of the protractor.

When the line C A is not, as in Fig. 35, long enough to admit of the above construction, place the lower edge of the protractor on that line, with the centre on C; then make a mark against the upper edge, at the line on the radiated edge which indicates the required angle (D), and draw D C.

The scale on the edge of the face of the protractor, and those on the back marked 30, 35, 40, &c., are plain scales, an inch being divided into the number of parts indicated by the figures.

The protractor has also on it a diagonal scale. The principle of the diagonal scale is explained in the Art. on Scales. The scales generally given are either inches divided into hundredths, with half-inches similarly divided on the right-hand side; or half-inches divided into hundredths, with quarter-inches on the right-hand side. To take off a given distance—let the distance be 4·35 units, this length being made up of the sum of 4 units, 3-tenths of an unit, and 5-hundredths of an unit. Look along the horizontal line marked 5 (for five-hundredths), place one point of the compasses on the point where this horizontal line cuts the oblique line from the point 3 (for three-tenths), and the other point of the compasses where it is intersected by the perpendicular from the point marked 4 (for four units).

79. *A Box of Marquois Scales.*—The Marquois Scales consist of two rectangular rulers and a right-angled triangle. The hypothenuse of the triangle is three times as long as the shortest side. On some of the edges of the rulers there are two scales, one on the actual edge of the ruler, the other close inside. The inner scale is a *natural* scale, in which an inch is divided into the number of parts marked in the *centre* of the scale, as 35, 40, 50, 60. The outer scale is an *artificial* scale, the divisions of which are three times the size of the accompanying natural scale—*i.e.*, these two sets of divisions bear the same proportions to one another as do the hypothenuse and the short side of the triangle, for a reason which will be explained. The scales on the *bevelled* edges of the rulers are natural scales, and are most convenient for *edge reading*. Let A B C (Fig. 36) be a position of the triangle, F G the ruler. The ruler remaining fixed, let the triangle be moved from A B C to A′ B′ C′; it is evident that the perpendicular distance A′ E, between the parallel lines A B and A′ B′, bears to the distance A A′, which the point of the triangle has moved (or to D D′ its equal), the same proportion which the hypothenuse A C does to the short side B C. A′ E is therefore one-third of D D′.

Thus by sliding the hypothenuse any given number of divisions, as marked on one of the artificial scales, the triangle will fall the distance represented by the same number of divisions on the natural scale.

To apply this principle, let it be required to draw two parallel lines a quarter of an inch apart.

On the scale of 40, one large division (or ten small divisions) will be equal to a quarter of an inch. Place the bevelled edge of the triangle carefully against the given line, and make the star point on the triangle agree with the zero point on the scale of 40. Then slide the triangle down (the ruler being held firmly with the left hand) until the star point coincides with the division on the outer scale marked 10, and draw a line along the bevelled edge. It will be, as required, $\frac{10}{40}$ths, or one-fourth of an inch from, and parallel to, the given line.

To apply the Marquois Scale to the construction of a given rectilinear figure on a given scale:—Let A B C D E F (Fig. 37) be the given figure of the dimensions marked, to be drawn on a scale of 20 feet to 1 inch. In this case, one division, on the natural scale of 20, being $\frac{1}{20}$th of an inch, will represent 1 foot on the drawing; of course, two divisions on the 40 scale, or three divisions on the 60 scale, would give a like dimension. Lay the bevelled edge of the triangle along A F. Then draw *bc*, *ee′*, *d d′* parallel, when the star point coincides with $3\frac{1}{2}$, 6, and 8 divisions on the scale of 20 (or a multiple of these divisions on another scale), and slide the triangle up far enough to draw D D′ at right angles to A F by the short side of the triangle. Now turn the rulers round, make the bevelled edge of the triangle coincide with D D′, and set the zero and star points together. Then move the triangle towards F, marking E at 12 divisions and F at 18 $(12 + 6)$; next move the triangle towards A, marking C at $1\frac{1}{2}$, B at $4\frac{1}{2}$ (or $1\frac{1}{2} + 3$), and A at $11\frac{1}{2}$ (or $7 + 4\frac{1}{2}$).

Join A B, C D, D E, and E F, to obtain the required figure on the given scale.

Problems in Plane Geometry.

The following are the problems of the most general application in Geometrical Drawing, and also for tracing on the ground the outlines and necessary details of works of defence. For the compasses may be substituted a cord fixed at one end when describing arcs on the ground, and a measuring tape or line when setting off distances.

80. *To bisect a given straight line* :—Let A B (Fig. 38) be the given straight line; with A and B as centres, and with any convenient radius, A C (greater than $\frac{1}{2}$ A B), describe circles intersecting in the points C and D; join these points by a line intersecting the given line in E. A B will be bisected in E.

N.B.—C D is perpendicular to A B.*

To apply this construction practically, double a rope so as to be able to take hold of its centre, and while its ends are held to the points A and B, the points C and D can be fixed by moving the rope until both its halves become tight. The point E can then be obtained.

When the given line is too long for the above construction, set off from each of its ends, A and B, equal distances as marked by the figures 1, 2, &c. (Fig. 39); a length convenient to bisect, as 3·3, will thus be obtained, the middle point of which, C, will evidently bisect A B.

When the given line, A B, is of known length, it may be bisected by measuring from either of its ends one-half of its length to obtain its point of bisection, C.

81. *To bisect a given angle* :—Let D A C (Fig. 40) be the given angle; make A C equal to A D; then from D and C as centres, and with equal radii, describe arcs intersecting in E; the line A E being then drawn, bisects the angle as required.

Obs.—The triangle D E C must be isosceles, but need not be equilateral.

To bisect an angle traced on the ground by pickets, or other marks, as D A C, fix a mark at any point, C, in the line A C, as far from A as possible, and another at D, in the line A D, making the distance A D equal to C A; double a cord so as to find its centre, and stretching it from C to D, mark the point equidistant from C and D, then the line bisecting the angle will pass through this point.

It may here be observed that any straight line traced in this way by pickets, &c., may be prolonged by placing other pickets so that they may appear to coincide with them; and that the point of intersection of two lines may be found by observing the coincidence with pickets placed in both lines.

82. *Through a given point, to draw a line perpendicular to a given line* :—

(1) When the point P is in the given straight line A B, and not near either end of it, as in Fig. 41: Set off equal distances P C, P D, in A B; from C and D as centres, with any suitable equal radii, describe arcs intersecting in E; join P E, which is the perpendicular required.

(2) When the point P is *not* in the given line A B, as in Fig. 42: From P as a centre, with any convenient radius, describe an arc, cutting A B in C and D; from C and D as centres, and with any suitable equal radii, describe arcs intersecting in E on the side of A B opposite to P; join P E: it is the perpendicular required.

These constructions may be employed on the ground, the point E being found as explained for Fig. 40, in Art. 81, by doubling a cord.

(3) When the point P is the line A B, but very near to one end, as in Fig. 43: Knowing that the angle in a semicircle is a right angle, fix any point, C, as a centre; with radius C P, describe a semicircle E P D, cutting A B in point D;

* In the figures the given lines are "thin and continuous;" the lines of construction—*i.e.*, those used to obtain the results, "thin and dotted;" and the resulting lines "thick and continuous." A given point is shown by a dotted circle described about it as a centre; and, generally, those lines which are only required for proof are omitted.

draw the diameter E D; join E P: it is the perpendicular required. This is a good practical mode.

Second construction (Fig. 45): Take any scale of equal parts; then with P as centre, and radius equal to three such parts, describe an arc cutting A B in C; with P as centre, and radius equal to four parts, and with C as centre, and radius equal to five parts, describe arcs intersecting in D; join P D: it is the perpendicular required. For $3^2 + 4^2 = 5^2$, *i.e.*, the square on C D equals the sum of the squares on P C and P D, and, therefore, C P D is a right angle.

(4) When the point P is nearly opposite to the end of A B (Fig. 44): Draw P C at a convenient angle to A B to be the diameter of a semicircle, bisect it in D. From D as a centre with radius D P, describe an arc cutting A B in E; draw P E: it is perpendicular to A B, because P E B is the angle in a semicircle.

83. *Through a given point to draw a straight line parallel to a given straight line*:—Let A B (Fig. 46) be the given straight line, and P the given point. From P let fall a perpendicular, P C, to A B, and from any convenient point, D, in A B draw a perpendicular, D E, making its length equal to P C: join P E to obtain the required line.

N.B.—This is the only construction here given, as it is the most convenient one for practical operations. The perpendiculars may usually be laid out by the eye, without *practical error in the parallelism* of the required lines.

84. *To construct an angle equal to a given angle*:—Let B A C (Fig. 47) be the given angle, and P the point in the given line, P D, at which it is required to construct an angle equal to B A C. With A and P as centres, and with an equal radius, draw the arcs B C and E D; with D as centre, and with a radius equal to the chord B C, draw an arc cutting D E in E: join P E to obtain the required angle D P E.

To set off angles on the ground:—This is most rapidly effected by means of a theodolite or sextant, but if they are not available, it may be done thus, with a cord only: A right angle may be traced as shown in Art. 82. An angle of 60° is obtained by tracing an equilateral triangle; and a line passing through any one angular point of this figure and the centre of the opposite side will give an angle of 30°. The angles of 90° and 30° being also bisected (see Art. 80), angles of 45° and 15° are obtained; and each of the above angles being added to any of the others, or substracted from them, by laying them out on the ground with equal radii, and adjacent to each other, give a few others: thus we get angles of 75°, 105°, 120°, 135°, and 150°.

85. *To divide a given straight line into any number* (n) *of equal parts*:—

(1) By trial with a pair of compasses.

Open the dividers to what appears to be the nth part of the line, step this distance along the line from one end, and if it be found either to exceed or to fall short of the nth part, correct the opening, and repeat the trial till the exact nth part is obtained.

Obs.—With care and a little practice it will be found that two or three trials are generally sufficient; but the process may be shortened by attending to the following rule:—

If n can be resolved into two factors (p and q), one of which, p, is any power of 2, as 4, 8, &c., the line should be first bisected (which can always be done by two trials); each part should again be bisected, and so on till the line is divided into p parts; each of these may again be divided into q parts, the qth part of one being obtained by trial as above.

(2, *a*) By construction suitable for work on ground, as A B (Fig. 48): Draw A C, making an angle of about 30° with A B, and through B draw B D parallel with A C. On A C and B D set off n—1 equal parts, each nearly equal to $\frac{1}{n}$th of A B; join n—1 C with 1 B; n—2 C with 2 B, &c., to divide A B into n equal parts.

(2, *b*) By construction on paper: Draw A C as above, setting off along it the equal parts 1, 2, 3, &c., up to n.

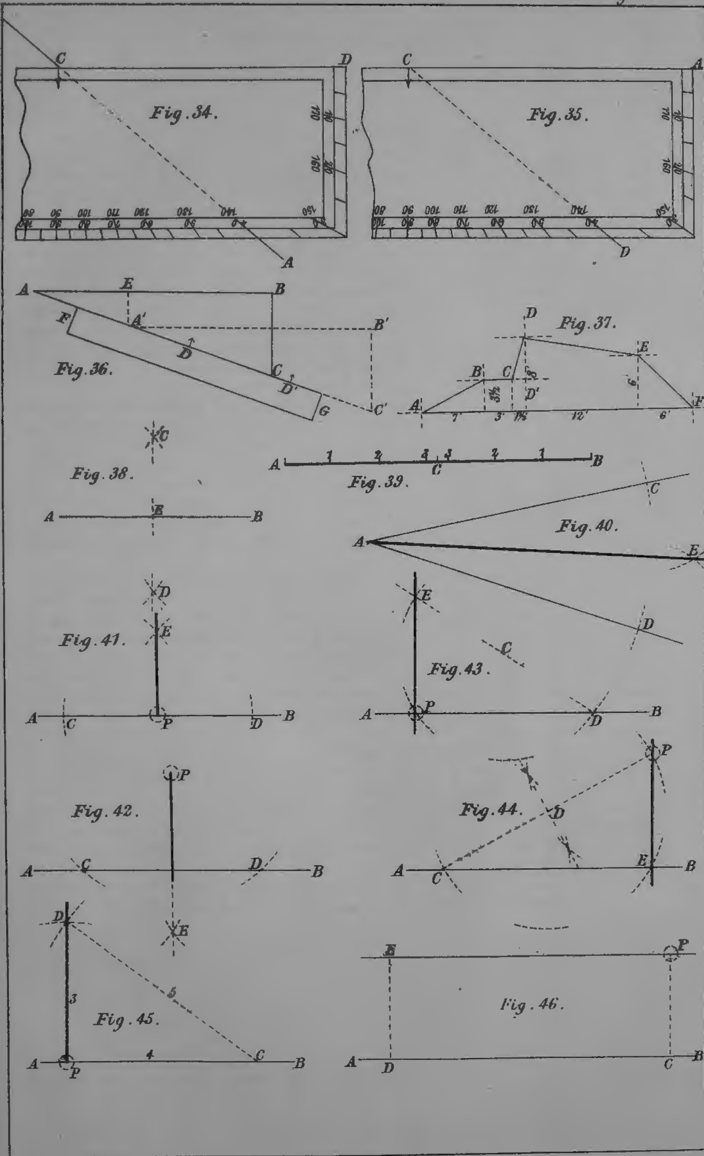


Fig. 34.
Fig. 35.
Fig. 36.
Fig. 37.
Fig. 38.
Fig. 39.
Fig. 40.
Fig. 41.
Fig. 42.
Fig. 43.
Fig. 44.
Fig. 45.
Fig. 46.

Join *n* B (with the Marquois Triangle), and through the other points in A C draw parallel lines. The intersection of these lines with A B will divide the latter as required.

(3) *To divide a straight line into a considerable number, n, of equal parts, by means of the Marquois Scales (Fig. 49):—*

Bisect A B in C, and describe the semicircle, A D B, and lay off B D a chord, equal to *n* parts (or any multiple of *n* parts), on any convenient scale on the Marquois; and setting the triangle on A D, which is perpendicular to A B, slide off the corresponding divisions on the Marquois Scale. In Fig. 49, A B is thus divided into 176 equal parts; and if A B represented a mile, divisions of hundreds and of tens of yards would be thus obtained.

86. *To reduce a given rectilinear figure to a triangle having an equal area:—*

Let A B C D E F G (Fig. 50) be the given figure. A G is taken as a base, and is produced outwards indefinitely. The point D, being the highest point of the figure above A G, is taken as the apex of the intended triangle.

Join A C, and through B draw B *b* parallel to A C, until it meets the base in the point *b*; it is evident that a line drawn from C to *b* (not shown in the figure) would include the same area as the lines C B and B A, as it cuts off a portion of the original figure, and adds thereto a portion of equal size. Thus, in place of the original sides A B and B C, a substitute C *b* is found.

Repeat a similar operation by joining D *b*, and through C draw the parallel line C *c*, meeting the base in the point *c*; join D *c* to obtain *a second substitute*, and in the figure in question to obtain also a side of the required triangle.

On the other side of the apex, similar constructions are necessary—*i.e.*, join E G, and through F draw F *f* parallel; then E *f* (not drawn in the figure) will be the first substitute. To obtain the next, join D *f*, and through E draw E *e* parallel, then join D *e* to obtain the other side of the triangle.

The number of operations necessary in a construction of this kind is determined by deducting three (number of sides in a triangle) from the number of sides in the given figure. In the illustration chosen, the original figure, A B C D E F G, consists of seven sides; four successive operations are therefore necessary to reduce it to a triangle of equal area.

Having thus reduced the original figure to a triangle of equal area, the area is found by measuring the base and perpendicular height of the triangle and taking half their product.

87. *To construct a square on a given line:*—On A B (Fig. 51), the given side, make an isosceles triangle, the equal sides of which, A C and B C, are of a convenient length (about = A B), then produce A C and B C *for their own length* to obtain the points D and E in the sides of the square produced. Along these lines measure A F and B G, each equal to A B, to complete the square. The entire construction requires only seven points to be marked, and is very convenient for practical work on ground. As a check to the accuracy of the work *the diagonals should be compared*, as they ought to be of the same length.

88. *To construct a regular pentagon on a given line:*—From either end (as B) of given line A B (Fig. 52) draw a perpendicular B C, equal in length to one-half of A B; produce A C, and make C D equal to B C; then A D is the length of the diagonal of the required pentagon. With this line A D as radius, from A and B as centres describe arcs intersecting in E, which point is the apex of the pentagon. The remaining angular points, F and G, are found by drawing arcs with radius equal to the side A B from E and B to obtain G, and from E and A to obtain F.

N.B.—The arcs described from A and B, with A D as radius, will pass through the points G and F of the pentagon. The various diagonals should all be equal.

89. *To construct a regular hexagon on a given line:*—On A B (Fig. 53) describe an equilateral triangle A O B; on A O and B O describe other equilateral triangles to obtain points C and D; finally, on C O and D O describe other similar triangles to fix the points F and G.

90. *To draw a tangent to a given circle through a given point*:—

(1) When the point is on the circumference of the circle as P (Fig. 54), join P with O, the centre of the circle, and through P draw A P, perpendicular to O P, to obtain the required tangent.

(2) When the point is outside the circle, as P (Fig. 55), two tangents can be drawn. Join P with O, the centre of the circle, bisect O P in D, and from D as a centre, with radius D O, describe a circle, cutting the given circle in two points, B and C; join P C and P B to obtain the required tangents.

Scales.

91. *A Scale* is a mode of expressing, by a divided or graduated line, the proportion which exists between a drawing and the object represented by it. Scales are used for the purpose of measuring lengths or distances on plans, maps, &c. Fig. 56, Plate VII., is the plan of part of a room, and Fig. 57, Plate VII., is the scale for the same plan. The breadth of the room is marked on the plan as being 12′, and it will be found on comparing the scale and the plan that the length of 12′ is the same in each. Any other dimension of the room can evidently be found by reference to the scale in Fig. 57. It will be also found that the length marked as 12′, both on the scale and on the plan, is actually 2″; the proportion between the plan and the full size of the room is therefore as 2″ : 12′. This proportion may be expressed by the fraction $\frac{2''}{12'} = \frac{2'}{12 \times 12} = \frac{1'}{72}$, which means that the dimensions (linear) on the drawing are $\frac{1}{72}$nd of the real dimensions represented.

This fraction, $\frac{1}{72}$, which expresses the proportion of the drawing to the real size of the object represented, is termed the *representative fraction* of the scale. The scale may be termed either "A scale of $\frac{1}{72}$," or, "A scale of 6 feet to 1 inch," since the length of 1 inch on the scale will represent 72 inches or 6 feet.

92. The representative fraction of any scale is determined by placing as the numerator of the fraction the length (usually given in inches) of some known distance or dimension *on the scale*, while the denominator is the real length represented.

Thus, the Ordnance Survey is principally on a scale of 1 mile to 1 inch, the representative fraction of which is—

$$\frac{1 \text{ inch}}{1 \text{ mile}} = \frac{1}{1760 \times 3 \times 12} = \frac{1}{63360.}$$

The method of expressing the scale of any drawing by its representative fraction has the great advantage of being intelligible to foreigners using English plans, or to Englishmen using foreign plans. Thus, a Russian officer using the Ordnance Survey of England, on the above scale of 1 mile to 1 inch, would be able to understand its proportion, and also, if necessary, to construct a scale of Russian measures to suit it, if he knew the scale to be $\frac{1}{63360}$, without being at all acquainted with the length of an English mile or an English inch.

93. *Comparative Scales* are those that have the same representative fraction, and which, therefore, would suit the same drawing. As an example—a French and an English officer jointly studying the plan of a fortress would probably each prefer to measure dimensions on a scale the units of which were familiar to him—*i.e.*, the Frenchman would prefer measuring in metres and kilometres; the Englishman in yards or miles.

94. The graduation of a scale should suit the notation in common use, which is decimal—*i.e.*, the principal or *primary divisions* of the scale should each represent either 1, or 10, or 100, or 1,000 of the required units; the left primary division should then be subdivided into 10 equal parts. By this means any number of units may be measured from the scale at one operation with a pair of compasses. Thus, 97 units, which is made up by the sum of 9 tens and 7 units, could be measured by placing one leg of a compass at the line marking the 9th

Fig. 47.

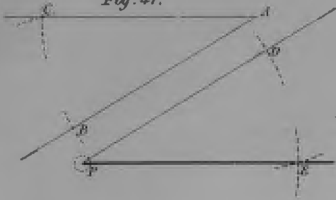


Fig. 48.

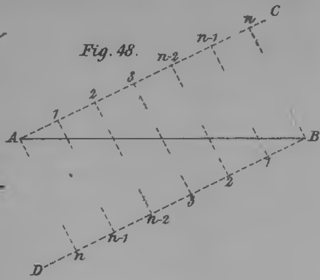


Fig. 49.

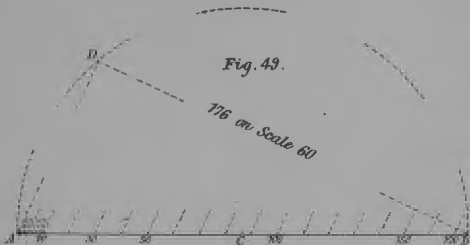


Fig. 51.

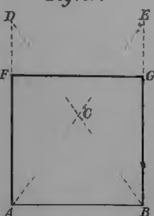


Fig. 52.

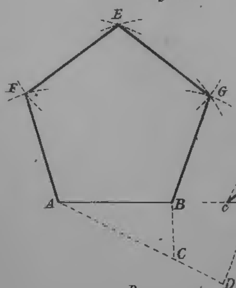
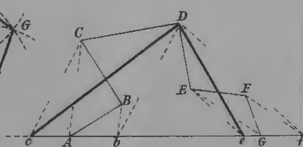


Fig. 50.



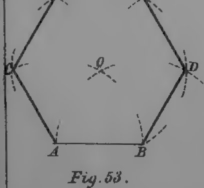


Fig. 53.

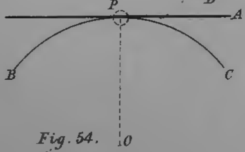
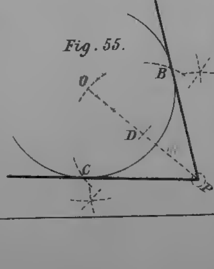


Fig. 54.

Fig. 55.



ten, and the other leg at the 7th unit. The 0 or Zero point of a scale should invariably be on the right of the left primary division, so as to measure 10's or 100's, &c., to the right, and the smaller divisions to the left of this point.

95. The construction of a scale requires two distinct operations: (1) the calculation necessary for determining its length in inches, and the number of units to be shown in that length; (2) the actual drawing of the scale.

The first is a case of simple proportion, which is conveyed either by the representative fraction, or by the given length, on the drawing, of some dimension as compared with the real length of that dimension.

96. If the following rule be adhered to, no difficulty ought to be experienced in calculating any required scale, however complicated it may apparently be.

RULE.—Ascertain, by proportion, the length in *decimals of an inch* of *one unit* of the required scale, and from this calculated length determine the entire number of units (10's, or 100's, or 1,000's, &c.) to be shown in the required scale.

A convenient length for the scales of *most* military plans is *about* 6 inches, *more or less*, to suit some decimal number of the primary divisions. A scale should, however, be made long enough to show the greatest length required to be measured from it.

97. As regards the drawing and graduation of the scale, Fig. 57 shows the usual mode of drawing, lettering, and figuring. The following hints will be found useful in order to ensure *accuracy of construction*, without which scales are useless :—(1) Work from the whole to get the parts—*i.e.*, calculate the entire length of the scale, and lay it down by measurement, which always can be correct to within $\frac{1}{100}$th of an inch. An error of not more than $\frac{1}{100}$th of an inch *in the whole length* of a scale is not of importance. (2) Choose a number of primary divisions for the entire length of scale, which is *not* a prime number. This is for convenience of subdivision afterwards. It is preferable, for instance, to subdivide a scale with 20 or 18 primary divisions, rather than one with 19 divisions. (3) Use a hard pencil (H.H.H.) with a fine point, and *press lightly* with it. Beginners sometimes use a B. pencil, with a point (so called) about $\frac{1}{10}$th of an inch broad, and express surprise at the result not being satisfactory. (4) Check your work before drawing it in ink, in the following manner, which is practically most accurate: Apply the straight edge of a piece of paper to the scale; mark off on the paper the divisions of the scale, then shift the paper to the right or left one or more divisions; if the marks on the paper continue to correspond with those of the scale, it may be assumed that the latter is accurately graduated.

EXAMPLES IN CONSTRUCTION OF SCALES.

98. Ex. 1. *Required a scale of $\frac{1}{30}$ to measure feet and inches.*

As denominator : numerator : : 1 unit of the scale : the length representing
(expressed in inches) 1 unit on the drawing.

Or as 30 : 1 : : 1 foot, or : 0·4 inch, which represents 1 foot (unit) on the scale.
(12 inches)

Since 0·4 inch represents 1 unit
4· „ „ 10 „
4·8 „ „ 12 „

To draw the scale, as in Fig. 58, Plate VII.

Take a line 4·8 inches long for the length of the scale, which will represent 12 feet; subdivide it into 12 equal parts for the primary divisions, each of which will represent 1 foot.

Divide the left primary division into 12 equal parts, each of which will represent 1 inch. Figure the scale as in the illustration.

99. Ex. 2. *Required a scale of yards to a plan on which a line* 0·51 *inch long represents* 9 *yards.*

	Units.		Unit.		Inch.		Inch.	
As	9	:	1	: :	0·51	:	0·0566	{ the length on the drawing of 1 unit (yard) of the scale.

Since 0·0566 inch represents 1 unit (yard)
0·566 „ will represent 10 „
5·1 „ „ 90 „

To draw the scale, as in Fig. 59, Plate VII. :—

Take a line 5·1 inches long for the length of the scale, which will represent 90 yards; subdivide into 9 parts for the primary divisions, each of which will represent 10 yards; subdivide the left primary division into 10 equal parts, each of which will represent 1 yard.

Figure the scale as shown.

The representative fraction of this scale is $\frac{\cdot 051 \text{ inch}}{9 \text{ yards}} = \frac{\cdot 051}{9 \times 36} = \frac{1}{635 \cdot 29}$.

100. Ex. 3. *Required a scale of Milan miles comparative to a scale of* 10 *English miles to* 1 *inch.*

1 *Milan mile* = 1808·81 *English yards.*

Here the known distance is 10 English miles, the dimension which represents it on paper is 1 inch, and the units requiring to be expressed on the scale are Milan miles (the length of which is known in English yards).

	English Miles.		Milan Mile.		Inch.		
As	10	:	1	: :	1	:	{ the length on paper representing 1 Milan mile;
	Yards.		Yards.		Inch.		
or	17600	:	1808·81	: :	1	:	0·1028 inch.

Since 0·1028 inch represents 1 unit (Milan mile)
1·028 „ „ 10 „
5·14 „ „ 50 „

To draw the scale, as in Fig. 60, Plate VII. :—

Take a line 5·14 inches long for the length of the scale, which will represent 50 Milan miles; divide it into 5 equal parts for the primary divisions, each of which will represent 10 Milan miles; subdivide the left primary division into 10 equal parts, each of which will represent 1 Milan mile.

The representative fraction of this scale is $\frac{1 \text{ inch}}{10 \text{ miles}} = \frac{1}{10 \times 1760 \times 36} = \frac{1}{633600}$.

101. Ex. 4. *On a Russian map* 25 *versts are represented by* 1 *archine; required a comparative scale of French kilometres.* 1 *verst* = 1500 *archines;* 1 *kilometre* = 1093·63 *English yards.*

This example may appear at first glance to be complicated, but it is not so in reality.

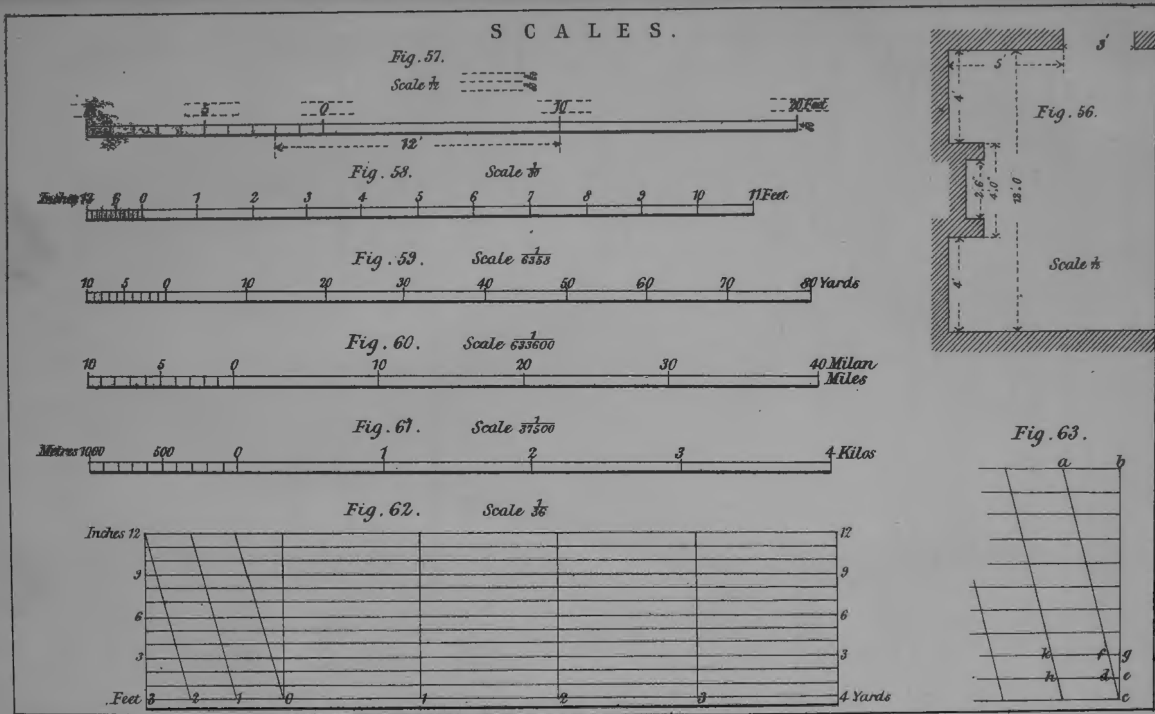
The representative fraction of the scale is $\frac{1 \text{ archine}}{25 \text{ versts}} = \frac{1}{25 \times 1500} = \frac{1}{37500}$.

Here the proportion between the real dimensions and those on the map is as 37500 : 1; and the units to be expressed are French kilometres, the length of which is given in English yards; consequently,

					Kilometre.		
As	37500	:	1	: :	1	:	{ the length on paper representing 1 kilometre;
					or 1093·63 English yards;		
					or 39370·58 „ inches;		
					Inches.		Inches.
or	37500	:	1	: :	39370·58	:	1·0498.

Since 1·0498 inches represents 1 unit (kilometre)
5·249 (or 5·25) inches represents 5 units.

SCALES.



Pl. VII. Figs. 56 to 63.

To draw the scale, as in Fig. 61, Plate VII. :—

Take a line 5·25 inches long for the length of the scale, which will represent 5 kilometres; divide it into 5 equal parts for the primary divisions, each of which will represent 1 kilometre; subdivide the left primary division into 10 equal parts, each of which will represent 100 metres.

102. *Diagonal Scales* are used for the purpose of obtaining the measurement of a more minute quantity than can be readily taken from a plain scale.

The principle of the diagonal scale is illustrated in Fig. 63, Plate VII. If $a\ b$ be a short length, of which the nth part be required, draw n lines, parallel to $a\ b$, and at *equal distances* (about $\frac{1}{10}$th to $\frac{1}{6}$th of an inch) apart: through b draw $b\ c$ (usually) perpendicular to $a\ b$; join $a\ c$. Then $d\ e$ will be the $\frac{1}{n}$th part of $a\ b$; $f\ g$ will be equal to $\frac{2}{n}$ths of $a\ b$, &c.

In Fig. 63 $a\ b$ is divided into 10 equal parts—*i.e.*, $d\ e = \frac{1}{10}\ a\ b$; $f\ g = \frac{2}{10}\ a\ b$; $h\ e = \frac{11}{10}\ a\ b$; $k\ g = \frac{12}{10}\ a\ b$, &c.

The mode of using a diagonal scale is best illustrated by an example. Fig. 62 is a plain scale of $\frac{1}{36}$, showing yards and feet, and a diagonal scale is added to show inches. It is therefore necessary in the diagonal scale to represent $\frac{1}{12}$th of the smallest dimensions shown on the plain scale. To do this, it will be observed that there are *twelve* equi-distant parallel lines drawn above the top line of the plain scale (making thirteen equi-distant parallel lines in all), having twelve equal spaces between them. Through the *primary* divisions of the scale, which in this case show yards, draw perpendiculars to the parallel lines, join the left hand secondary division (the 2 feet) with the upper left hand extremity of the top line of the scale, and through the other secondary divisions (the 0, 1 foot) draw lines parallel to this oblique one.

To use the scale:—Let 13 feet 7 inches be required at a single measurement. This length being equal to 4 yards 1 foot 7 inches, the measurement must be made on the 7th parallel line (for the 7 inches), and will be comprised between the points on that line extending from the perpendicular which marks the 4th yard to its intersection with the oblique or diagonal line from the 1st foot.

103. Table of some of the Principal Units of Linear Measure, in terms of English Feet, Yards, and Miles.

Locality.	Unit.	Feet.	Yards.	Miles.	Remarks.
Austria ...	Zoll (12 Linien)...	·08640	·02880	—	—
,, ...	Fuss or Schuh (12 Zolle)...	1·0371	·34568	—	—
,, ...	Elle	2·5586	·85289	—	—
,, ...	Klafter (6 Fuss)...	—	2·0741	—	—
,, ...	Ruthe (10 Fuss)...	—	3·4568	—	—
,, ...	Meile (4,000 Klafter)	—	8297·0	4·7142	—
,, ...	Meile (Geographische)	—	8101·0	4·6026	$\frac{1}{15}$ Degree
England ...	Inch	·0833	·02777	—	—
,, ...	Foot	1·0000	·33333	—	—
,, ...	Yard	3·000	1·000	—	—
,, ...	Ell	—	1·2500	—	—
,, ...	Fathom	—	2·000	—	—
,, ...	Pole or Perch ...	—	5·5000	—	—
,, ...	Chain (100 links)	—	22·000	—	—
,, ...	Furlong	—	220·000	·125	—
,, ...	Mile (common) ...	—	1760·000	1·000	—
,, ...	Do., Geographical or Nautical ...	—	2025·200	1·1506	$\frac{1}{60}$ Degree.
,, ...	League		5280·000	3·000	—

TABLE OF SOME OF THE PRINCIPAL UNITS OF LINEAR MEASURE, ETC.—*Continued.*

Locality.	Unit.	Feet.	Yards.	Miles.	Remarks.
France ..	Milimètre	·0033	·0011	—	New Measures.
,, ...	Centimètre	·032	·0109	—	
,, ...	Decimètre	·328	·1093	—	
,, ...	Mètre	—	1·0936	—	
,, ...	Kilomètre	—	1093·63	·62138	
,, ...	Myriamètre ...	—	10936·33	6·2138	
Prussia ...	Fuss (Rhenish foot)	1·0297	·3432	—	—
,, ...	Elle	2·1879	·7294	—	—
,, ...	Schritt...	2·4714	·8238	—	—
,, ...	Klafter or Faden (6 Fuss)	—	2·0596	—	—
,, ...	Ruthe (12 Fuss)...	—	4·1192	—	This Ruthe is divided into tenths and hundredths, for surveying, &c.
,, ...	Meile (2,000 Ruthe)	—	8238·0	4·6807	—
Rome ...	Piède	·9665	·3222	—	—
Russia ...	Archine	2·3332	·7777	—	—
,, ...	Sachine (3 Archines)	—	2·3332	—	—
,, ...	Verst (500 Sachines)	—	1166·6	·6628	42,000 inches.
Saxony ...	Fuss	·9292	·3097	—	—
,, ...	Meile (24,000 Fuss)	—	7432·8	4·2227	—
Spain ...	Pulgado	·077	·0257	—	—
,, ...	Palmo (9 Pulgados)	·695	·2283	—	—
,, ...	Pié (Castilian) (12 Pal.)	·9273	·3091	—	—
,, ...	Vara (3 Piés) (4 Palmo)	2·7682	·927	—	—
Sweden ...	Foot (10 inches) ...	·9742	·3247	—	—
,, ...	Alner	1·9484	·6494	—	—
,, ...	Mile (18,000 Alners)	—	11690·0	6·6423	—

MENSURATION, INCLINATIONS OF SLOPES, ETC.

104. The following simple rules are necessary, in order to find the areas of the different parts of the profile of a parapet (*see* Figs. in Plate VIII.).

(1) The area of a *rectangle* is equal to the product of the two adjacent sides.

Note.—The area and one side being given, the other is found by dividing the area by the known side.

(2) The area of a *right-angled triangle* is equal to half the product of the two sides containing the right angle.

(3) The area of *any triangle* is equal to half the product of any side and the perpendicular from the opposite vertex.

$$\text{Area A B C} = \frac{\text{A C} \times \text{B}\,p}{2} \quad \text{(Fig. 65).}$$

Note.—As by Art. 86 any rectilinear figure drawn to scale can be reduced to a triangle having an equal area, this rule affords the means of finding the area of any rectilinear figure.

(4) To find the area of a *trapezoid*, add together the two parallel sides, then divide by two to obtain the mean length $\left(\frac{\text{A D} + \text{B C}}{2} = m\ n \text{ in Fig. 66}\right)$, and multiply by the perpendicular distance between them.

$$\text{Area A B C D} = m\,n \times d\ \text{B in Fig. 66.}$$

If the area of a trapezoid, the distance between the parallel sides (*i.e.*, depth of ditch *d* B), and the slopes, be given, the length of the parallel sides may be thus found. Divide the area of the trapezoid by the distance between the parallel sides for the mean length $\left(\frac{\text{Area A B C D}}{d\text{ B}} = m\,n\right)$. Add and subtract half the bases of the slopes for the lengths at top and bottom.

$$m\,n \pm \frac{\text{A}\,d + e\,\text{D}}{2} = \text{A D and B C.}$$

105. The principal application of the above simple rules in mensuration consists in determining the dimensions of a ditch such as *g, h, i, k*, so that it shall have the same area as the parapet *a, b, c, d, e, f* (Fig. 67), in order that sufficient earth may be supplied by the ditch to form the parapet.

The parapet is divided, as shown in the figure, into two trapezoids and two right-angled triangles; the ditch into two right-angled triangles and one rectangle.

Area of parapet, *a, b, c, d, e, f*, consists of—

(1) 1st Trapezoid, *a b p o* .. $= \frac{b\,p + a\,o}{2} \times p\,o$

(2) 1st Triangle, *c p d* .. $= \frac{c\,p \times p\,d}{2}$

(3) 2nd Trapezoid, *d o n e* .. $= \frac{d\,o + n\,e}{2} \times o\,n$

(4) 2nd Triangle, *e n f* .. $= \frac{e\,n \times n\,f}{2}$

Area of ditch, *g, h, i, k*, consists of:—

(1) Triangle (escarp), *g m h* .. $= \frac{g\,m \times m\,h}{2}$

(2) Rectangle (in middle), *m h i l* $= m\,l \times m\,h$

(3) Triangle (counterscarp), *k l i* $= \frac{k\,l \times l\,i}{2}$

106. The inclinations of slopes are expressed by fractions, in the following manner:—The line of the slope is supposed to be the hypothenuse of a right-angled triangle; the sides of the right angle being a *vertical* and a *horizontal* line. The vertical line, which represents the height of the slope, is made the numerator of the fraction; while the horizontal line, which represents the base of the slope, is made the denominator of the fraction.

Thus, in Figs. 68 and 69, the dotted lines represent vertical and horizontal lines, and the slopes of the other lines are represented by the fractions accompanying each.

This method of expressing slopes is generally more convenient than by referring to the inclinationsofthe slopes in degrees, both for drawing on paper and for erecting slopes, and also for measuring the inclinations of existing slopes. For instance, if, in Fig. 70, a slope of $\frac{1}{1}$ is required to be drawn passing through the point *p*, and meeting the ground line *g g*, the *vertical* line *p a* can be obtained by any ordinary plumb-line; and then by measuring the height *p a*, and from *a* setting off the *horizontal* line *a b* equal to *a p*, a point *b* in the required slope will be obtained; the line *p b* being produced to its intersection *c* with the ground line, will be the required slope.

Again, suppose an existing slope (*a c*, Fig. 71) has to be measured; if from any convenient point *a* in the slope, the horizontal line *a b* is set off, and from any convenient point *b* or *b′* in *a b* the vertical line *b c* or *b′ c′* is drawn meeting the slope, the lines *a b* and *b c* being measured, the inclination of the slope *a c* will be expressed by the fraction $\frac{b\,c}{a\,b}$ or $\frac{b'\,c'}{a\,b'}$; and this will be correct of whatever magnitude *a b* and *b c* are taken, provided they are respectively *horizontal* and *vertical*; *practically*, however, the longer these lines are, the better.

When the ground is practically level, the bases of slopes may, of course, be measured on the ground itself.

Geometrical Drawing.

107. As remarked in the opening paragraph of the section, a knowledge of the principles of geometrical drawing is necessary for the student in Fortification. This necessity is really twofold: firstly, because constant reference is required to the various drawings (plans, &c.) by which works are represented on paper, on a scale more or less small; secondly, because a knowledge of geometrical drawing is requisite, in order to be able to mark out on the ground the various works of defence, when the works may be said to be *drawn* full size or on a scale of $\frac{1}{1}$.

The following short description of the principle and method of construction of the ordinary geometrical drawings is therefore given.

108. *The Projection* of an object is a representation of it, made by imaginary lines or rays, proceeding from some point in space through every point of the object, and meeting a given plane or surface, on which they form the required representation.

If an observer, in a room, sees a landscape through a window, and while remaining stationary himself marks the outline of the landscape, *as it appears to him*, on the window, that outline will be a projection of the landscape on the glass of the window as the *plane of projection*, the eye of the observer being here the *point of projection.*

Thus, every ordinary picture, so far as respects its sketch or outline, is merely a projection of the objects represented: the eye of the artist being the *point of projection*, and the paper or canvas being the *plane of projection*, which is here supposed to be vertical, and to be placed between the eye of the artist and the landscape.

A projection is Orthographic when the *projecting lines* are parallel to one another, the point of projection being supposed infinitely distant from the plane of projection.

In the actual drawing of fortification it is not necessary to get every point of the object to be drawn really projected, for since the object is usually bounded by plane surfaces, those surfaces will be shown by drawing their intersecting lines or edges; to do which, all that is necessary is to be able to fix the points in which they (the edges) meet, for the lines joining these points will then represent the boundaries of the surfaces, and the spaces between them the surfaces themselves.

Thus, if Fig. 72 represents a triangular pyramid, it is only necessary, in order to be able to draw it, to fix the four points A, B, C, and D correctly; for by joining these points in the manner shown in the figure, the six lines and the three visible surfaces of the figure are obtained.

The Plan of an object is its orthographic projection (in its natural position) on a horizontal plane of projection, which is represented by the drawing-paper.

Plans are used in drawing to show the true horizontal lengths and breadths of the object they represent.

The Trace of a work is a plan of its guiding or magistral line. In Field Fortification this line is the highest or *crest* line of the parapet, while in Permanent Fortification it is the line of the top of the escarp wall.

The Elevation of an object is its orthographic projection (in its natural position) on *any* vertical plane of projection, represented by the drawing-paper; it shows the true heights of the various parts, and it gives an idea of the appearance of the object when viewed perpendicularly to the plane of projection.

The Section of an object is the representation of the surface that would be exposed, supposing the object to be cut through by a plane passing in any required direction. This imaginary cutting plane is usually vertical.

The Profile of au object is a section made by a vertical plane, cutting the object in a direction perpendicular to its length. A profile evidently shows the true breadths and heights or depths, and is the only section that does so.

Plans and profiles of works are the only drawings that are ordinarily required, as by means of them we obtain a correct representation, on any convenient scale, large or small, of the true lengths, breadths, and heights of every part of the work drawn.

Elevations are, however, necessary in order to make more apparent the general appearance of the objects represented, more especially when they (the objects) are complicated ones.

All these different kinds of drawings—viz., Plans, Profiles, Sections, and Elevations—are usually made on the same piece of paper, and, at first, great difficulty is experienced in endeavouring to comprehend their nature and method of construction. This principally arises from the drawing-paper being treated in the plan as a horizontal plane; while, in Profiles and Elevations, the same paper is considered a vertical plane.

109. In explanation of the foregoing, supposing we have to make the plan of a line of parapet, of which a profile is given in Fig. 73, where the bases and heights are figured. Here the horizontal surfaces covered by the slopes of the parapet are evidently A G = 6', G H = $4\frac{1}{2}$', H I = $1\frac{1}{2}$', I K = 12', and K F = $5\frac{1}{2}$'. The point (D) in the profile, being the highest or crest point, represents the magistral line. Draw a line, D D (Fig. 74), to represent this line in the plan, making it of the length required to be shown; parallel to it, and at the distance from it of the bases I K = 12' and K F = $5\frac{1}{2}$', draw the lines E E and F F, represented in profile by the points E and F; and on the other side of D D in the plan draw the lines C C, B B, and A A, parallel to it, and at the distance apart of the bases shown in the profile—viz., H I = $1\frac{1}{2}$', G H = $4\frac{1}{2}$', and A G = 6'—to represent in the plan the lines shown in the profile by the points C, B, and A.

Suppose, now, that the line of parapet, thus far only partly represented in the plan, is to be terminated at its extremities by slopes of $\frac{3}{1}$ and $\frac{2}{1}$, on its right and left respectively:

To draw the plan of the slope of $\frac{3}{1}$ on the right produce D D, making D *d* = $\frac{1}{3}$ D I in profile; through the point *d* draw the line A F, perpendicular to the line of the work; this line A F will be the intersection of the terminating slope of $\frac{3}{1}$ with the surface of the ground; from this line set off *e* E = $\frac{1}{3}$ K E in profile, *c* C = $\frac{1}{3}$ H C in profile, and *b* B = $\frac{1}{3}$ G B in profile; join A B, B C, C D, D E, and E F, to complete the figure.

If the line A F terminating the work on the ground had been first assumed, instead of the point D, the same result would have been obtained by setting off the four bases *b* B, *c* C, *d* D, and *e* E equal, respectively, to $\frac{1}{3}$rd of the heights of the points B, C, D, and E in profile above the ground.

To draw the plan of the terminating slope of $\frac{2}{1}$ at the other end or extremity of the parapet, a similar process to the one just mentioned must be gone through, taking care to make the bases *b* B, *c* C, *d* D, and *e* E *one-half*, respectively, of the heights of the points B, C, D, and E in profile above the ground.

110. We will now suppose that a Section of the above line of parapet is required on the line X Y (Fig. 75).

This line X Y is here supposed to represent the plan of a vertical plane, cutting through the parapet. This section line intersects the lines of the plan in the points *l*, *m*, *n*, *o*, *p*, and *q*. The distances *l m*, *m n*, *n o*, *o p*, and *p q* will be the bases of the several slopes in the section.

To draw the section, select any line (X Y, Fig. 75) for the ground or base line along which mark the bases *l m*, *m n*, *n o*, *o p*, and *p q*; from the points *m*, *n*, *o*, and *p* erect perpendiculars to the base line, making them of the several heights shown in the profile (Fig. 73). The angular points of the section will thus be obtained, and by joining these points the section itself will be completed, as shown in Fig. 75 by the shaded portion.

111. Let us now suppose that, in addition to the section on X Y (Fig. 74), AN ELEVATION on the same line is also required to be constructed, as shown in Fig. 75.

In this case it must be imaginedt hat the object to be represented is viewed in directions perpendicular to the line X Y in the plan (Fig. 74), where imaginary lines are shown drawn from the points A, B, C, D, perpendicular to and meeting X Y. These perpendiculars intersect X Y in the points *r*, *s*, *t*, and *v*.

To draw the elevation, transfer the points *r*, *s*, *t*, and *v* to the ground line of the elevation (Fig. 75); from *s*, *t*, and *v* erect perpendiculars, making them equal, respectively, to the known heights above the ground of the points B, C, and D in the profile (Fig. 73). The angular points of the elevation, in addition to those fixed by the section, will thus be obtained, and by drawing the proper lines through these points the elevation itself will be completed.

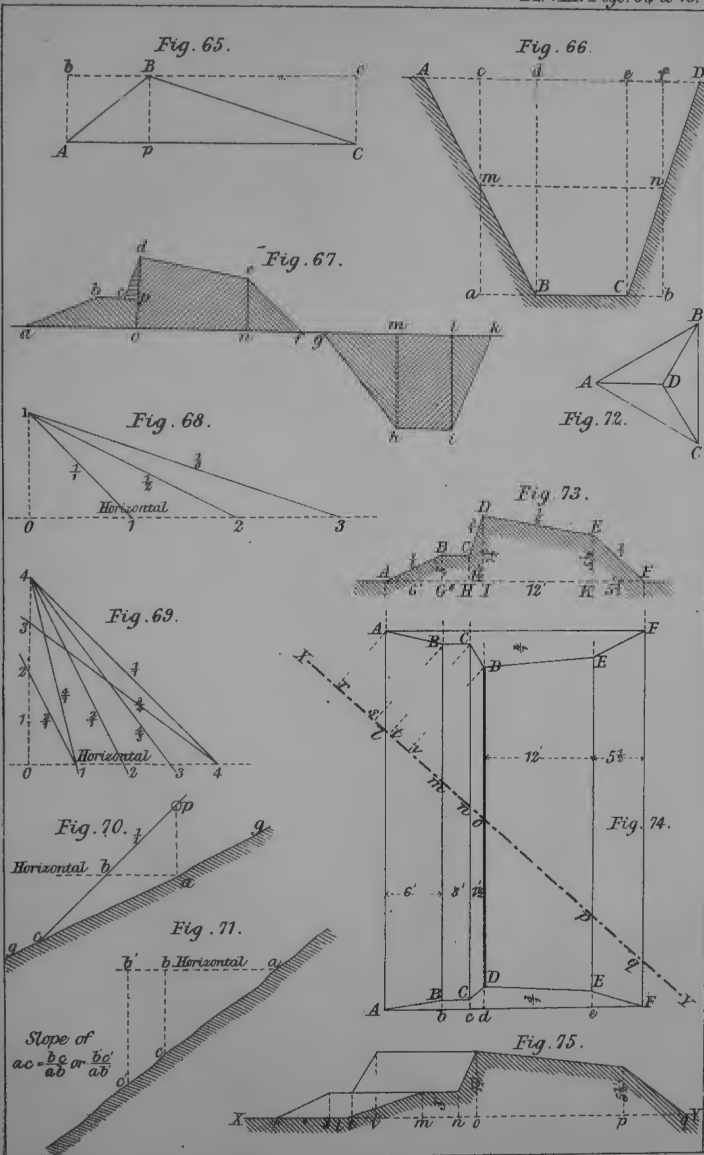


Fig. 65.
Fig. 66.
Fig. 67.
Fig. 68.
Horizontal
Fig. 69.
Horizontal
Fig. 70.
Horizontal
Fig. 71.
b Horizontal
Slope of ac = bc/ab or b'c'/ab'
Fig. 72.
Fig. 73.
Fig. 74.
Fig. 75.

SECTION III.

FIELD FORTIFICATION.

CHAPTER I.

THE PROFILES OF REGULAR FIELD WORKS. WALLS, HEDGES, ETC. HASTY ENTRENCHMENTS.

Object of Fortification; principles to be fulfilled; causes of the difference between Field (or temporary) and Permanent Works; object of the Parapet and Ditch; command and relief; command given to field works; object of trenches, as a means of obtaining cover, their advantages and defects; thickness of parapets, how regulated; table of penetrations; banquette, its use and dimensions; slope of banquette; interior slope; superior slope; use of glacis; interior and exterior crests; crest plane; exterior slope; berm; ditch, escarp, bottom of ditch, depth of ditch, counterscarp; triangular profile to ditches; width of ditches; example of a profile; usual mode of determining the profile of a work; remblai and deblai; two examples of the calculation of a profile; loopholes on a parapet, and their varieties; Stockades, their uses and construction; how to prepare walls and hedges for defence; shelter trenches and pits; rifle pits; gun epaulements and gun pits.

112. Preliminary Observations.—Fortification, or the art of fortifying, as a practical science, has for its object the strengthening of positions held by troops, so as to enable a small force to withstand the attack of a greater number. It has been usually treated in two divisions—viz., *Field Fortification* and *Permanent Fortification;* the former (Field) referring to the class of works made during a campaign for temporary defensive purposes; the latter (Permanent), as its name implies, treating of works intended to exist for an unlimited period, which may be constructed to secure the vulnerable frontiers, the leading communications, the arsenals, dockyards, or ports of a country from capture or destruction.

The division of the science of Fortification into the two branches of Field and Permanent is convenient for purposes of instruction, but it is to be borne in mind that the principles to be followed in each are the same, and it is only the difference of the conditions under which the two kinds are constructed that causes the difference between them.

113. The principles to be fulfilled in every fortification, whether Permanent or Field, are the following :—

(1) It should cover or protect the defenders from the view and the fire of an enemy.

(2) It should enable the defenders to see the enemy and to use their weapons with effect, over the whole ground within range of fire, with the least possible exposure to themselves.

(3) The assailant's access to the position should be difficult and obstructed, in order that he may be kept as long as possible under the fire of the defenders.

Such being the principles to be fulfilled in all defensive works, it is evident that their nature greatly depends on the stature of men, and on the effects of the weapons used both in the attack and in the defence.

114. Permanent Fortifications are usually constructed in time of peace with reference to future wars. From three to five years are required for their construction, for which all the means at the disposal of the State are available; and the advantages obtained ought to be as perfect as the natural strength of the position and the expenditure authorized for the purpose will permit.

FIELD WORKS, on the contrary, are almost invariably constructed in haste, often in view of an enemy, and even sometimes under his fire; the resources available for their construction are also generally very limited; consequently it is but seldom that any degree of perfection is attainable with field works, and all that can be usually attempted in defending a position by them, is to fulfil the three conditions before mentioned as nearly as is possible in the time and with the means available.

In most cases any fortified position will consist partly of natural, partly of artificial works; the position being selected for defence from its natural advantages, which will be made the most of, as time and circumstances permit, by the addition of artificial works of defence.

115. Where no natural obstacles exist, troops are placed under cover of a bank of earth, termed the *Parapet*, the earth for which is either obtained from a *Ditch* excavated in front (Fig. 76, Plate IX.), or from a *Trench* in rear as well as from a front ditch (Fig. 77, Plate IX.); or (as in Fig. 78, Plate IX.) only from a trench in rear.

The three figures in Plate IX. are typical of the usual profiles given to field works, the choice between the three depending principally on the time available for the construction of the work; but partly also on the position of the work, its exposure to fire, and liability to assault.

116. The Parapet with Ditch (1st type) gives the best cover to the ground in rear (interior of work), and affords the greatest command to the defenders, owing to the height of the parapet ($7\frac{1}{2}'$ or $8'$) being the greatest; also, the ditch can be made more of an obstacle than in the other profiles, as it is the largest excavation. On the other hand, this profile requires the longest time to construct. It is the type of a solidly constructed work in cases where time is not particularly pressing.

117. The 2nd type of profile Fig. 77 (Parapet with Ditch and Trench), is used in cases where good cover to the defenders is required *close to the parapet*, while time also is pressing. In this type the parapet is lower than in type 1 (usually $6'$ or $6\frac{1}{2}'$ in height), and is therefore a smaller mass of earth; and as this reduced quantity of earth is obtained from two excavations, viz., the ditch in front and the trench in rear, which are simultaneously executed, the work can be constructed in a *very short time.* This important fact is the chief recommendation of the profile. Its drawbacks are—that good cover is only afforded to the defenders when in the trench; that the ditch necessarily is not so great an obstacle; and also that the trench (like all trenches occupied by men) becomes more or less a quagmire in wet weather, and is difficult to drain.

But, notwithstanding these drawbacks, the profile is typical of that given to most field works constructed for the defence of positions liable to immediate attack, but requiring good cover from field artillery and musketry fire for their defenders.

The sides of the trench may either be with slopes, as shown, or be made in steps.

Trenches are made, when necessary, behind parapets of the height shown in Fig. 76, in order to increase the cover to the defenders when a great amount of fire may be expected. The slope of the banquette and the front of the trench would then be made with steps, so as to increase the cover afforded.

118. The 3rd type of profile, where a low parapet only is required, is shown in Fig. 78, where all the earth for the parapet is obtained from the trench, the dimensions of the latter being regulated accordingly. In this case, the defenders to be under cover must be in the trench: they are not even hidden from view if on the ground in rear.

Siege parallels, and sometimes lines of intrenchment connecting works of

TYPES OF FIELD PROFILES.

Fig. 76. *No. 1. Parapet and Ditch.*

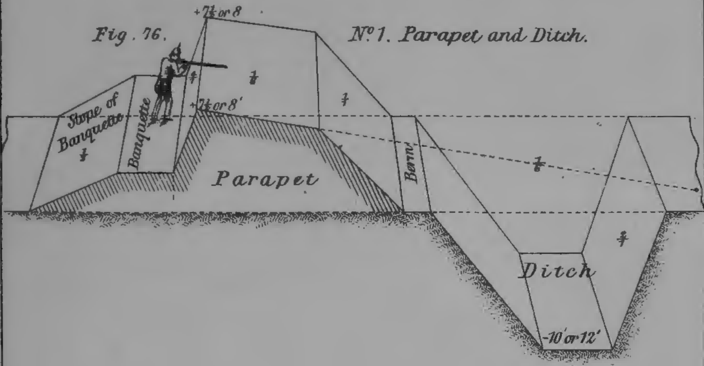


Fig. 77. *No. 2. Parapet with Ditch and Trench.*

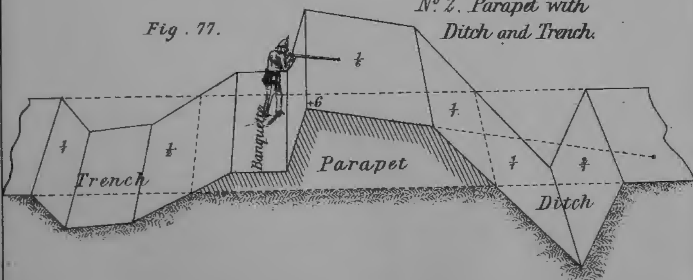
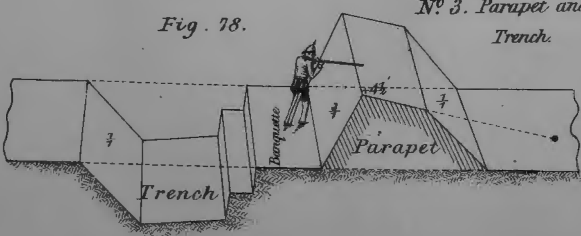


Fig. 78. *No. 3. Parapet and Trench.*



importance, have profiles of this type, which has the advantage of affording cover quickly, since every foot of depth of the trench may be said to afford two feet of cover; and, further, if properly constructed (with steps, &c.), it is no impediment to the forward movement of the defenders, who can charge over it on a wide front. These advantages peculiarly fit it for certain positions.

The disadvantages of the trench formation were referred to in Art. 117.

N.B.—The term *Ditch* is applied to an excavation outside a parapet; that of *Trench* to one in rear of the parapet. The earth from each is used to form the *Parapet*, but the former is intended as an obstacle to an assailant, while the latter is for the purpose of covering or screening the defenders.

119. It must be understood that the three profiles referred to are *types* only, the dimensions of either being altered to suit particular circumstances. The details are so various that an endless number of actual profiles might be given.

DIMENSIONS, SLOPES, ETC., OF PROFILES OF FIELD WORKS (SEE FIG. 79).

120. The *Command* of a parapet is the height of its *crest* (or highest point) above the ground on which it is constructed, as D R.

One work is said to have a Command of Observation over another in its front, when it is of sufficient height over the front work to prevent an enemy,

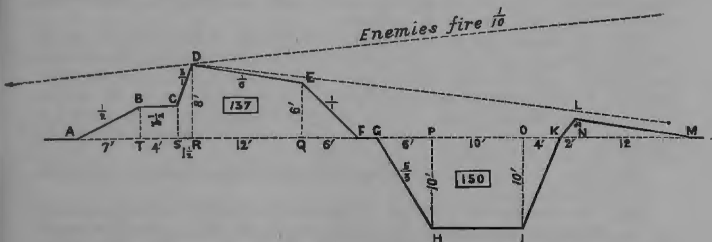


FIG. 79.—Scale $\frac{1}{180}$.

A T.	Base of slope of banquette.	B T. or C S.	Height of banquette above ground.
T S.	Ditto of the banquette.	D R.	Ditto of crest above ground; or *the command* of the parapet.
S R.	Ditto of interior slope.	E Q.	Height of exterior crest above the ground.
R Q.	Ditto of superior slope; also thickness of the parapet.	P H. or O I.	Depth of the ditch.
Q F.	Ditto of exterior slope.	L N.	Height of the glacis.
F G.	The berm.		
G P.	Base of the escarp.		
P O.	Width of bottom of ditch.		
O K.	Base of counterscarp.		
K N.	Base of reverse slope of glacis.		
N M.	Ditto of superior slope of glacis.		

when in possession of that work, being able to see into the interior of the higher work. An additional command of 4′ or 5′ is requisite for this purpose.

The *Relief* of a line of work is the height of the crest of its parapet above the bottom of the ditch; or, the sum of its *command* and *depth of ditch.*

Fig. 79 is the profile of a parapet, having a thickness of twelve feet and a command of eight feet, with the bases and heights figured, so as to show the ordinary dimensions of a work having a good field profile.

121. The *Command* should be sufficient to give cover to the defenders standing on the ground inside. Infantry are assumed not to exceed 6′ in height, and to protect men of that height, within a moderate distance of the parapet (say 20′ from the crest), from projectiles just clearing the crest, it is generally admitted that the command should be, for a parapet on a level site, 8 feet or more.

A greater command than 8 feet is necessary, either when more than the usual cover is required, or when an enemy is able to occupy higher ground within effective range, and so fire into the work with an increased angle of descent. Thus, in Fig. 80, a parapet constructed at P to cover the ground in rear from the

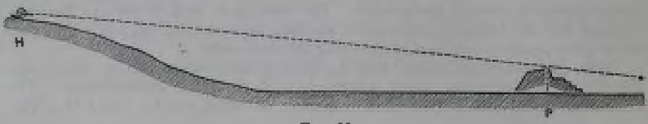


FIG. 80.

fire of an enemy on the higher ground at H, would evidently require an increased command; but to be able to find out *how much greater* it must be, the reader is referred to the subject of "Defilade."

Field works seldom have parapets with a command greater than 12 feet, on account of the large increase of labour required to construct them; the extra labour required (measured by the amount of earth) increasing at a much more rapid rate with each increase of command.

122. If a parapet had to be constructed on the top of the height H, in the preceding figure, facing the low ground, it would be so advantageously situated that proper cover would be given with a *less command* than 8 feet. The necessary command would depend on the actual height of H, with reference to the ground in front within effective range. Where this superiority of site is very decided, a command of 5′ or even 4½′ *may give as good cover* to the defenders as would be afforded by an 8-feet parapet on a level site.

This is one of the advantages attending a commanding position; others will be hereafter referred to.

123. The *thickness* of a parapet is measured horizontally between the *crest* (D, Fig. 79) and the *exterior crest* (E). In Fig. 79, the line R Q evidently measures this. The thickness depends on the amount of fire, and on the calibre of the artillery likely to be brought against it; and it should be sufficient to prevent the passage of projectiles, even after a considerable resistance.

Parapets are usually made 3 feet thick when exposed only to musketry fire; 6 feet to 9 feet thick when exposed to light field artillery (9-Pr.); 9 to 12 feet thick against heavy field guns (16-Pr., &c.); and 12 to 18 feet thick against guns of position.

The actual penetrations of Common Shell into stiff clay at Shoeburyness, in 1882, with ranges under 1,000 yards, were found to be :—

9-Pr.	... ...	4 feet.
16-Pr.	... ...	6 „
13-Pr.	... ...	7 „

In cases where parapets are *only exposed to oblique fire*, as in the side faces of redoubts, &c., it is usual to make their thickness only two-thirds of what it should be to withstand *direct* fire.

124. To enable Infantry to fire over a parapet is the object of the *Tread of the Banquette* (B C, Fig. 79); or, as it is more usually termed, the *Banquette*. This is a raised pathway, on which the defenders stand when required to fire over a parapet. The parapet is then said to be "manned." The banquette is made 4½ feet below the level of the crest, as that height, 4½ feet, is the greatest over which infantry can fire above the ground on which they stand.

The banquette is usually made 4′ wide, but it is sometimes (on the least important parapets) made 3′ wide. Formerly two ranks of defenders were allotted to the principal parapets of a work; this, however, is no longer required, as the maximum fire effect is obtained from a single line of men, at intervals of one yard, on a banquette. The defenders of any parapet will consist of the "shooting line" on the banquette, at one yard intervals, with a "support" of about one-half the number at the foot of the banquette slope, or in the rear trench.

The surface of the banquette is given a slope of about 2 inches to the rear to drain off water; but for purposes of calculation, and in drawing profiles of works, it may be treated as horizontal.

125. The *Slope of the Banquette* (A B, Fig. 79) is the term applied to the slope leading up to the banquette from the interior of the work. Its object is to allow the defenders to get on or off the banquette without inconvenience, and for this purpose it is given a base twice its height, or a slope of $\frac{1}{2}$.

In works where interior space is valuable, if the parapets have a command greater than usual, this slope of the banquette may be replaced by steps, as in the annexed sketch (Fig. 81), where the dotted line shows the ordinary position of the slope of the banquette, and illustrates the object of replacing it by steps to save interior space. More ground *screened from fire* is also afforded by the parapet. These steps, however, have the disadvantage of requiring much extra material, such as planking, &c., in their formation, and the communication by them to the banquette is not so convenient as with the earthen slope, especially at night.

FIG. 81.

126. The INTERIOR SLOPE of the parapet (C D, Fig. 79) is made as steep as possible. In Field Works its usual slope is $\frac{3}{1}$ or $\frac{4}{1}$. The object of this steep slope, when a banquette for musketry is used, is to enable the soldier to stand close to the crest, so that he may fire over the parapet with ease, using the crest as a rest for his musket.* As the nature of ground is such that it will not stand by itself at so steep a slope, it must be kept up artificially by what is termed a *Revetment*, the mode of making which will be pointed out subsequently. See chapter on "Revetments."

127. The upper surface of the parapet, termed the SUPERIOR SLOPE (D E, Fig. 79), inclines to the front sufficiently to enable the musketry fire directed parallel to its slope to defend the top of the counterscarp or further side of the ditch. This will be effected whenever the superior slope produced passes within 3 feet of the ground at the counterscarp.

This slope is evidently an evil, though a necessary one, as it weakens the parapet at the crest, and the more so the steeper it is; but it is a less evil than having the ground outside the ditch undefended by the fire from the parapet. An inclination of 1 in 6 ($\frac{1}{6}$) is usually sufficient for the superior slope on a level site. A slope of $\frac{1}{4}$, or any intermediate one, may be employed, but steeper slopes than $\frac{1}{4}$ for superior slopes are not recommended, as the parapet at the crest would be too much weakened: if with a slope of $\frac{1}{4}$ the top of the counterscarp cannot be defended from the parapet, the ground in front of the ditch should be raised by means of a *Glacis*, as seen in Fig. 79, so as to keep an assailant exposed to the fire of the parapet as long as possible. This is of great importance; and, as will be described in the next chapter, obstructions are placed in the way of an enemy to delay him under the fire of the work *while he is close to it.*

* To resist an assault the defenders should at the last moment mount on to the superior slope, in order to oppose the enemy when attempting to scale the parapets. The steep interior slope, 4½′ in height, is a great obstacle to their doing this with ease and readiness. After the first assault on the works of Sebastopol, all the banquettes were raised to within 90 centimetres (1 yard) of the crest, to facilitate getting on to the superior slopes. If a step, 1′ 6″ high and broad, were built on the banqnette at the foot of the interior slope, the same advantage would be gained, while the defenders could fire either (1) standing on the ordinary banquette, (2) kneeling on the top of the step, or (3) standing on the step.

The glacis should have a gentle slope to the front corresponding to the superior slope of the parapet, so as to be grazed by the musketry fire of the latter. The parapet should have a command over the glacis of at least 5 feet, in order that the attacking troops may not be able to fire into the work when on the glacis.

128. The Interior Crest, more usually termed simply The Crest, of the parapet, is the line of intersection of its Superior and Interior Slopes. It is the *Magistral Line* in Field Fortification. This line is the one that is first laid down in drawing a plan of a work on paper, or which has to be fixed before tracing it on the ground, as it is the principal line in the work, and it is most important to fix its position properly; its length also determines the number of defenders required for a field work.

129. The Exterior Slope of a parapet, which is the slope most exposed to fire (E F, Fig. 79), should not be steeper than what is termed the *natural slope of the earth*, or the slope at which the earth used will stand without artificial support. With the generality of soils this slope is $\frac{1}{1}$.

In works which are expected to be exposed to a heavy fire of artillery (such as the batteries at a siege, &c.), or when the soil is light and sandy, the exterior slope should be made less steep, $\frac{2}{3}$ or $\frac{3}{4}$.

In some cases, which are, however, exceptional, the exterior slopes of works may be revetted steeply, so as to save space outside the work so treated. This may be the case when one work is constructed inside another to prolong its defence. See Art. on "Reduits."

The intersection of the Superior and Exterior slopes is called the Exterior Crest, and, as before mentioned, the thickness of a parapet is the distance (measured horizontally) between the *crest* and the *exterior* crest.

130. The Berm (F G, Fig. 79) is a space left between the parapet and the ditch; its object is to relieve the *escarp* from the pressure of the parapet by removing the weight a certain distance away. This pressure is very great, as the weight of earth when well rammed will usually be about $1\frac{1}{2}$ tons per cubic yard. The breadth of the berm depends upon the height of the parapet and the nature of the soil; it may vary from 1 to 6 feet.

The berm facilitates the construction of and repairs to the parapet, as a line of workmen may be employed on it to throw the earth on to the parapet as required. It has, however, the great defect, in a parapet of ordinary height, of affording a footing to an assailant, safe from the direct fire of the work, at a critical moment of the attack. It is sometimes dispensed with altogether, but when indispensable it may be occupied with obstacles, and in many cases it may be cut away, after the work is constructed, without weakening it, by producing the exterior slope till it meets the escarp slope.

131. We now come to the Ditch, which supplies the earth required to form the parapet, and also acts as an obstacle (though by itself it is not a very formidable one) to the advance of an enemy, who may have reached it. An inspection of the profiles given will show that the ditch in itself is no great obstacle; for the assailants having reached its edge will not hesitate to jump into it, to be out of reach of the direct fire of the work, whatever may be the steepness of the counterscarp, and once in it, *if not exposed to flanking fire*, as is generally the case in field works, may spread along it, and then rush into the work and close with the defenders *in a body*, to prevent which is a great desideratum in the defence.

132. The Escarp (G H, Fig. 79), or side of the ditch nearest to the work, is made as steep as the nature of the soil will allow; as the steeper it is made, the greater the obstacle it will be. Its slope in ordinary ground is $\frac{2}{1}$, sometimes it can be made steeper; but in weak soils, and when works are required to last a considerable time, it will generally be impracticable to give the escarp a steeper slope than $\frac{1}{1}$, unless it is artificially supported.

133. The Bottom of the Ditch (H I, Fig. 79) is considered horizontal;

but in executing a work it would generally be given a slight inclination from sides to centre, to prevent water lodging at the foot of the slopes.

134. The Depth of the Ditch (P H, Fig. 79) should be at least 6 feet to be considered as an obstacle, and it may vary from this to 12 feet, according to circumstances. A depth of 12 feet is usually considered the maximum that should be given to the ditches of Field Works, on account of the difficulty of throwing up the earth from greater depths; but this rule, like most *general* rules, may be frequently departed from with advantage, when particular circumstances require it.

135. The Counterscarp (K I, Fig. 79), or outer slope of the ditch, can be made steeper than the escarp, as it has not, like the latter, to resist the pressure of the parapet. It is usually formed at $\frac{2}{1}$, $\frac{3}{1}$, or $\frac{4}{1}$, according to its height and the nature of the soil.

136. As the ditches of field works are generally without flank defence, it will be advantageous, whenever that is the case, to form the ditch triangular in section—*i.e.*, with the escarp and the counterscarp meeting in a point at the bottom. This construction gives the greatest depth and breadth, and prevents anything like a settled formation of hostile troops in the ditch; and with the same object in view, the defenders should be plentifully supplied with hand-grenades. The ditches of the redoubts of the celebrated lines of Torres Vedras were generally of this shape.

The Width of the Ditch (G K, Fig. 79), always estimated at the top, ought not to be less than 12 or 13 feet in works which may have to stand an assault; as, otherwise, planks sufficiently long could be brought up to bridge it.

137. The Glacis (K L M, Fig. 79) has already been alluded to, as being used in certain cases to keep the ground in front of the ditch under the fire of the parapet. It is also employed to screen obstacles of various kinds from the view, and protect them from the fire, of an enemy. In the latter case, the glacis is formed with the earth from a trench made in its rear, as shown in Fig. 82; care

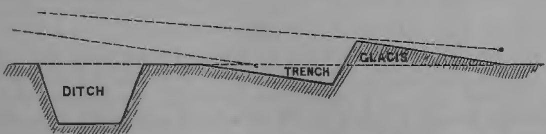


Fig. 82.

being taken that the slopes of both glacis and trench are such that they are exposed to the musketry of the work. A small glacis is also frequently made merely to get rid of superfluous earth, when the ditch is made larger than is required for the formation of the parapet.

138. In selecting the profile proper for a work, the nature of the ground both in front and rear, and the degree of cover required, *determine the command;* the *thickness of the parapet depends* upon the projectiles it is to resist, and on its chances of exposure to fire. These two main dimensions principally determine the section of the parapet.

The dimensions of the ditch have then to be determined. In order to do this, either the width may be assumed, and then the depth calculated (the slopes of the sides having been previously settled); or the depth may be assumed, and the requisite width then calculated. In most cases it is usual to assume the depth (as that to a great extent depends upon the nature of the soil, which may fix a limit to it), and then to calculate the requisite width. If a triangular ditch be selected, the slopes of its sides will fix both the width and depth, as soon as the area is known.

139. The French term *Deblai* is given to the mass of earth in the ditch before being excavated, and that of *Remblai* after it is built up in the work. The *Remblai* will be frequently greater than the *Deblai*—*i.e.*, the earth on being excavated and built up will have increased in bulk, and this increase of bulk will vary according to the soil and the care with which the work is constructed; but experience has shown that this increase need not occur in ordinary soils, provided the workmen are properly superintended, so as to insure the earth being well consolidated. In the calculations that follow it will not be taken into account, and also the ditch will be assumed to be equal in length to the parapet; therefore, the *area of the profile of the ditch* (or *ditch and trench*) will be equal to the *area of the profile of the parapet.*

Two examples are given below to illustrate this method; they are given in full for the sake of clearness, and are apparently long, but with a little practice the necessary calculations may be performed in a very short time.

140. Ex. 1.—*A line of intrenchment has to be constructed on level ground, with a command of $7\frac{1}{2}$ feet, a parapet of 12 feet thick, and a banquette 4′ wide; the interior slope to be $\frac{3}{1}$, superior slope $\frac{1}{6}$, exterior slope $\frac{1}{1}$, slope of banquette $\frac{1}{2}$. The ditch to be 12 feet deep, the escarp to slope $\frac{2}{1}$, and the counterscarp $\frac{3}{1}$; required the width of the ditch.*

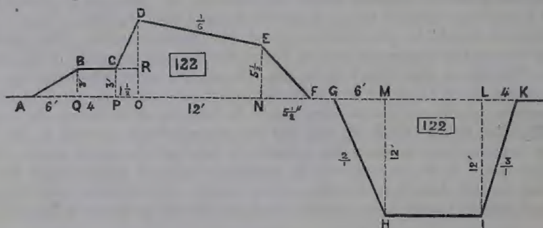


FIG. 83.

In Fig. 83, which is a *hand-sketch* of the profile, D O will be $7\frac{1}{2}'$ and O N 12′; as the superior slope is $\frac{1}{6}$, the point E will be $\frac{12}{6}$, or 2′ under the point D, consequently E N will be $5\frac{1}{2}'$; N F will therefore be also $5\frac{1}{2}'$. The banquette B C being $4\frac{1}{2}'$ under the crest, C P and B Q will each be $7\frac{1}{2} - 4\frac{1}{2} = 3'$; P O, which is equal to C R, is equal to $\frac{RD}{3} = \frac{4\frac{1}{2}}{3} = 1\frac{1}{2}$; and $AQ = 2\,BQ = 6$ feet. Thus the bases and the heights of the parapet are easily found.

In the ditch, the depth M H or L I is given as 12′; $GM = \frac{MH}{2} = 6'$, and $LK = \frac{LI}{3} = 4'$. M L or H I, the width of the ditch at the bottom, is therefore *the only unknown dimension* in the profile.

To calculate the area of the parapet, the areas of the four figures A B R O, C R D, D O N E, and E N F (two of which are trapezoids, and two are right-angled triangles) are found separately and added together, thus—

Area of 1st trapezoid of parapet	$= \frac{5\frac{1}{2} + 11\frac{1}{2}}{2} \times 3$	$= 25\frac{1}{2}$	square feet.
„ 1st triangle „	$= \frac{1\frac{1}{2} \times 4\frac{1}{2}}{2}$ ...	$= 3\frac{3}{8}$*	„
„ 2nd trapezoid „	$= \frac{7\frac{1}{2} + 5\frac{1}{2}}{2} \times 12$	$= 78$	„
„ 2nd triangle „	$= \frac{5\frac{1}{2} \times 5\frac{1}{2}}{2}$ ...	$= 15\frac{1}{8}$	„
Area of profile of parapet ...	... ...	122	„

* This triangle will be the same in any parapet the interior slope of which is at $\frac{3}{1}$.

Then the ditch in profile will also be 122 square feet, and its width at bottom will be found thus :—

	Area of ditch		= 122 square feet.*
Deduct	Escarp triangle ...	$= \frac{6 \times 12}{2} = 36$	= 60 ,,
	Counterscarp ditto ...	$= \frac{4 \times 12}{2} = 24$	—
	Rectangle in ditch		= 62 ,,
	Width of ditch at bottom		$= \frac{62}{12} = 5$ feet nearly.†

The width at bottom of the ditch may also be found thus, as its profile is a trapezoid :—

Area of ditch... ... ... $=$ 122 square feet.

Mean width ... ... $= \frac{122}{12} = 10$ feet.†

Top width ... ... $= 10 + \left(\frac{6+4}{2}\right) = 15$,,

Bottom width ... ... $= 10 = \left(\frac{6+4}{2}\right) = 5$,,

141. Ex. 2.—*A line of intrenchment is to be constructed in haste, on level ground, with a command of 6 feet, and thickness of parapet 9 feet, cover in rear being obtained by means of a trench 3′ deep in front, with a step 1½′ in height and breadth, and 3½′ deep in rear, with rear slope $\frac{1}{1}$, the breadth of trench at bottom being 6 feet.*

The parapet to have the ordinary slopes; the banquette to be 4′ broad, communicating with the ground level by a step.

The ditch to be triangular in section; slope of escarp $\frac{1}{1}$, in prolongation of exterior slope of parapet (i.e., without a berm), slope of counterscarp $\frac{2}{1}$.

Required the depth and breadth of the ditch.

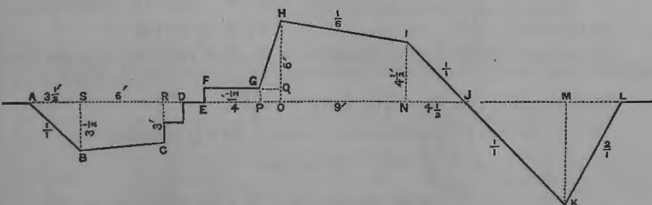


FIG. 83*a*.

In the hand-sketch (Fig. 83*a*) of the profile, the data enable the dimensions of the parapet and trench to be thus fixed :—

Parapet.	*Trench.*
H O = 6 feet.	A D = A S + S R + R D
G P or F E = 6′ − 4½′ = 1½′	= 3½′ + 6′ + 1½′
$G Q = P O = \frac{4\frac{1}{2}'}{3'} = 1\frac{1}{2}'$	= 11′
E P = F G = 4′	R C = 3′
N J = I N = 4½′	S B = 3½′

* It is convenient to show the superficial area on the profile thus :— | 123 |

† No account need be taken of depths less than 3 inches.

In this example the parapet is formed with the earth obtained from both the trench and ditch: and, as the dimensions of the trench are given, the size of the ditch must be regulated so as to supply sufficient earth; in other words, the area of the trench and ditch together must equal that of the parapet in profile; therefore, to obtain the area of the ditch, subtract the area of the trench from that of the parapet.

Parapet.	Area of rectangle F E O Q	$= 5\frac{1}{2}' \times 1\frac{1}{2}'$	$= 8\frac{1}{4}$ sq. feet.
	" 1st triangle	$= \dfrac{4\frac{1}{2} \times 1\frac{1}{2}}{2}$	$= 3\frac{3}{8}$ "
	" Trapezoid H O N I	$= \dfrac{6 + 4\frac{1}{2}}{2} \times 9$	$= 47\frac{1}{4}$ "
	" 2nd triangle	$= \dfrac{4\frac{1}{2} \times 4\frac{1}{2}}{2}$	$= 10\frac{1}{8}$ "
	Area of profile of parapet		$= 69$ "
Trench.	Area of A S B...	$= \dfrac{3\frac{1}{2} \times 3\frac{1}{2}}{2}$	$= 6\frac{1}{8}$ sq. feet.
	" Trapezoid S C...	$= \dfrac{3\frac{1}{2} + 3}{2} \times 6$	$= 19\frac{1}{2}$ "
	" Step rectangle...	$= 1\frac{1}{2} + 1\frac{1}{2}$	$= 2\frac{1}{4}$ "
	Area of profile of trench		$= 27\frac{7}{8}$, say 27 sq. feet.
	∴ Area of profile of ditch	$= 69 - 27 = 42$	"

To obtain the dimensions of the ditch it is evident, *in this particular case*, that as the base of the escarp is equal to its height, and that of the counterscarp is only one-half its height, the area of the escarp triangle must be double that of the counterscarp triangle, and the former will be two-thirds of the ditch area and the latter one-third of the same.

Therefore area of escarp triangle ...	$= \frac{2}{3}(42) = 28$ square feet.	
And of counterscarp triangle	$= \frac{1}{3}(42) = 14$ "	
From either of which areas the depth of the ditch may be found to be ...	$\sqrt{56}$	$= 7\frac{1}{2}'$ (nearly).
And its width to be	$7\frac{1}{2} \times 1\frac{1}{2} = 11\frac{1}{4}$.	

Another mode of deducing the dimensions of the ditch from its profile area (the slope of escarp being $\frac{1}{1}$, and that of counterscarp $\frac{2}{1}$) may be followed, thus—

Let d = depth, then breadth $= d + \frac{1}{2} d = \dfrac{3d}{2}$

Now as $\frac{1}{2}$ (breadth × depth) = area of ditch (a triangle)

$$\tfrac{1}{2}\left(\frac{3d}{2} \times d\right) = 42 \text{ sq. feet.}$$

$$\therefore \frac{3d^2}{4} = 42 : \text{whence } d = \sqrt{\frac{42 \times 4}{3}} = \sqrt{56} = 7\tfrac{1}{2}' \text{ (nearly).}$$

The above examples are sufficient to show the manner in which the dimensions of the ditch of any required parapet may be quickly calculated.

142. The area of the profile of a parapet may also be found by drawing the profile on a scale sufficiently large (6′ or 8′ to 1 inch), and afterwards reducing it to a triangle of equal area; the base and height of this triangle can then be measured, and the area found.

The method of calculating areas by first drawing the figure to scale has the disadvantage of requiring drawing instruments to be at hand, and is not so rapid and cannot be so accurate as the preceding method of calculation, which, in addition to rapidity and accuracy, has the further recommendation of requiring but a pencil and a piece of paper to effect it.

143 It must be remembered that these calculations are only approximate; for it has been assumed that there is no increase of bulk in the earth after it has been excavated, and also that the length of the ditch is the same as that of the parapet, neither of which may be the case; but they are sufficiently near the truth to enable a work to be marked out on the ground and commenced without loss of time.

The ditch, as determined by the preceding calculations, will usually be too great, when there is any error, and it will therefore generally be a good precaution to make a ditch a little narrower than its calculated approximate breadth, as it can be widened at any time in the progress of the work, or deepened afterwards. This is preferable to running the risk of making it too large at first.

144. STOCKADES (Plate X.).—A *stockade* is a timber parapet made by planting one or more rows of timbers upright and close to one another, so as to be proof against rifle bullets.

Loopholes (openings to fire through) are made at intervals, usually of not less than 2′ 6″, although men can fire at 2 feet intervals if required.

The timbers are usually from 6 inches to 14 inches thick, or in diameter; from 10 to 15 feet long, pointed at top or spiked if there is time available, and they should be sunk 3 or 4 feet in the ground.

A "riband" or stout beam should be secured horizontally to the timbers on the inside; near the top, sawyers' dogs may also be freely used to keep the timbers together.

145. *Stockades* have the advantage of combining a good musketry parapet and of an obstacle to an enemy; and unless breached by artillery fire (which is not easy to effect) they require to be surmounted either by means of ladders, or by forming a breach in them by a charge of powder or of gun cotton exploded against them. They can also be guarded against surprise by a *very small number* of men.

The details will vary according to the length of timber used; whether it is round or square; and whether one or two rows of loopholes are required.

In all cases it is desirable that an enemy should not be able to make use of the loopholes, should he get close to the stockade.

146. Loopholes are made between two timbers, one-half being taken out of each.

In stockades of 10 to 12 inches thick, loopholes may have the following dimensions (Fig. 95):—

Interior width, 8 inches.	Exterior width, $2\frac{1}{2}$ inches.
,, height, 12 ,,	,, height, 4 ,,

Two saw cuts in each timber are required for a loophole, the wood between them being removed afterwards.

The dimensions for loopholes in timber stockades, as laid down at Chatham, are shown—those for squared timbers in Fig. 95, and those for round timbers in Fig. 96 of Plate X.

In Fig. 88 are shown the heights over which a soldier can fire when either (1) Standing, (2) Kneeling, or (3) Lying down. The positions of loopholes in Stockades, Walls, &c., must be regulated accordingly, with reference to the level on which the defenders are intended to stand.

147. Fig. 84 represents in profile a stockade made with timbers 10′ long, for a single row of loopholes, the ground acting as a banquette: the "riband" (in this and other examples) is placed just below the loopholes.

To prevent an enemy closing on the stockade and then making use of the loopholes, a small ditch is excavated on the outside, the earth from which is principally used as a small glacis, so as to raise the ground in front, and some of it is piled against the stockade.

148. In Fig. 85 the timbers are 11 feet long, the loopholes are 6 feet above the ground, which prevents an enemy making use of them; a banquette, 3′ broad, is made from the earth obtained from the shallow trench in rear.

149. Fig. 86 shows a stockade of squared timbers, openings being left at intervals by using short timbers as a substitute for loopholes. An outside ditch, similar to that in Fig. 84, is not shown in this figure, but is equally desirable.

150. Fig. 87 shows a stockade for a double row of defenders, and, therefore, two tiers of loopholes. The timbers should be 13 feet long, so as to project 9′ above ground, if sunk 4′ below it.

The upper tier of loopholes is shown as suiting a banquette of planks 2′ 6″ above ground. This height enables the lower row of defenders to fire, lying down underneath it close to the ground level. A shallow, gently sloping trench, 1 foot deep in rear and 6 feet broad, is shown as accommodating the shooting line. The plank banquette rests on cross timbers, at intervals of 6′ to 10′, which are secured to a riband at the stockade end, and to posts at the other end.

Instead of the lower rank firing in the kneeling position they may fire standing, if a trench $2\frac{1}{2}$′ deep and 3 feet distant from the stockade be made, as shown by dotted lines in this figure—also in Fig. 102, Plate XI.

151. With longer timbers details may be varied. The upper loopholes may be raised, and with them the banquette. The lower rank might then be arranged to fire from the ground itself, either kneeling, or, perhaps, standing. The example given is a good type of a line affording a double tier of fire from infantry well placed.

152. Figs. 89 to 94, inclusive, show the method of arranging timbers, when not regularly squared. Round timbers, if time, &c., permit, should be roughly squared on the sides, as in Fig. 89; or, if this be not done, they may be arranged with the intervals between them protected by others, as indicated in Figs. 92—94.

Half timbers may be arranged as shown in Fig. 89. Quarter timbers may be arranged as shown in Fig. 90.

153. Defence of Walls (Plate XI.).—Many of the details given for Stockades, such as position and height of loopholes, methods of forming banquettes, also of preventing an enemy making use of the loopholes, apply equally to the defence of walls. In the case of stockades, loopholes are made before the timbers are erected, and of the dimensions most suitable; with walls, loopholes in them, or notches at their tops, have to be made with the implements available (often unsuitable), and at best they are rough apertures, the dimensions of which only approximate to what, theoretically speaking, are most desirable.

Stockades are erected in chosen positions, and are seldom, if ever, exposed to a frontal fire of artillery; walls, on the other hand, have to be occupied in positions already fixed, and frequently with a certainty of being subjected to artillery before being assaulted. For this reason cover for the shooting line must often be provided, in rear of a wall occupied for defence, by means of trenches, the earth from which may either be used for a banquette or, if placed well in rear of the wall, simply as a parapet. A trench and parapet would frequently be required to cover the supports to the shooting line, in the absence of existing cover.

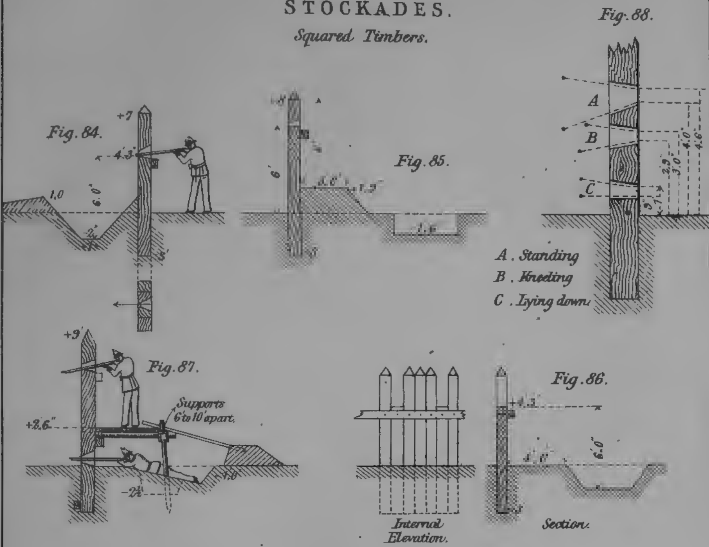
As a rule, *thin* walls battered by artillery are not breached by its fire: the projectiles go through the walls, making small holes therein, and detaching splinters inwards. The projectiles used would generally be common shells with percussion fuzes, in order that the shells should burst immediately they are through the wall. It is therefore necessary, when a preliminary cannonade has to be withstood prior to attack, to provide cover for the defenders up to the time when they are required to man the line defended: this is, when the enemy's infantry advance to the attack.

154. If loopholes can be cut in walls (suitable tools being available), the outside opening should be about 3″ broad and 4″ high, the loophole *splaying* (or getting broader) inwards according to the angle of fire required; but usually, in a 14″ wall, being 10″ wide and 12″ high on the inside.

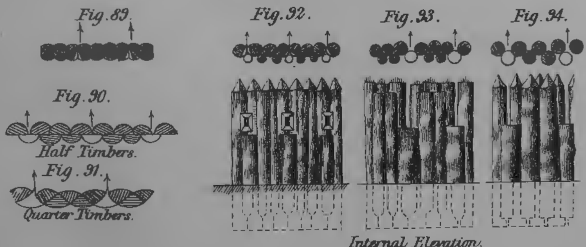
But when roughly formed, as is usually the case, a loophole in a brick wall would be made by first loosening and detaching a *header* on the outside of the wall, and the adjacent *stretcher* on the inside, and then by improving the opening formed as well as circumstances permit. An infantry soldier with his bayonet can loosen the mortar around a stretcher without difficulty, and when this brick is removed and the outside header exposed, the latter can generally be knocked out

STOCKADES.

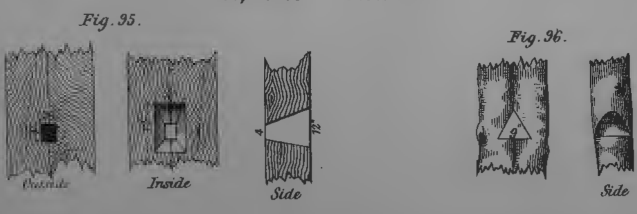
Squared Timbers.



Round Timbers.



Loopholes in Stockades.



DEFENSIBLE WALLS.

Fig. 98. *Fig. 97.*

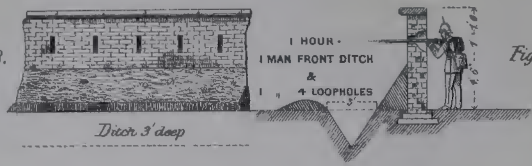
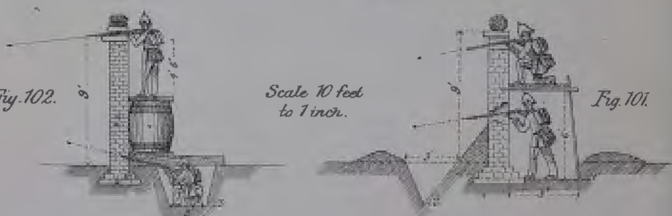


Fig. 100 *Fig. 99.*

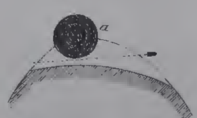
Fig. 102. *Fig. 101.*



Scale 10 feet to 1 inch.

LOOPHOLES.

Fig. 107.



(a) Bullet Proof Log.

Fig. 103.

Top

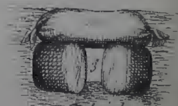
Fig. 104.

Section on line of Fire.

Fig. 108 *Brushwood Loophole Weight 4lbs.*

Fig 105 *Inside view of a Sand bag Loophole*

Fig. 106. *Inside top bag requires to be supported underneath by a stick &c.*



Outside

by a crowbar, &c., or men can work on both sides of it (inside and outside the wall), and pick out the mortar with their bayonets.

Examples of Walls made Defensible (Plate XI.).

155. A wall, 4 feet in height, serves as a parapet without any preparation.

Head cover should be added as may be practicable, and to prevent an enemy closing on it and firing from it, a ditch 2 to 3 feet deep may be excavated on the outside, the earth from which should be scattered in front.

A wall 6 feet in height would usually be notched at the top, or a banquette of earth or sand-bags made in rear for the defenders to fire *over* the top, head cover being desirable also.

156. In Figs. 97, 98 a wall 7′ high is shown as defensible. The shooting line stand on the ground and fire through loopholes. The enemy is prevented from closing on the wall by means of the ditch, 3 feet deep, and the excavated earth being piled up against the wall.

In Figs. 99, 100 a similar wall is prepared by notching the top, providing head cover to the defenders, who would fire standing on the banquette, the earth for which is obtained from the rear trench. The arrangement in front is the same as in Fig. 97.

157. In Figs. 101, 102 are shown two examples of walls, arranged for a double tier of fire, the height of the wall being 9 feet. In Fig. 101 the upper rank kneel and the lower rank stand to fire, the level of the banquette surface being arranged accordingly. The front of the wall is treated as in preceding examples. Head cover is also shown for the upper rank. The details for the two ranks of the shooting line in this example might also be copied from those shown in Fig. 87, in Plate V., for the stockade.

In Fig. 102 the lower rank fire kneeling in a trench, the loopholes being close to the ground; the upper rank fire over the wall, from a banquette of planks resting on casks.

158. In defending walls and stockades, it is to be noted that a row of loopholes close to the ground enables the surface thereof to be well watched; this may be of great importance in guarding against a night attack, or in observing the approach of an explosion party.

Walls Protected from Field Artillery.

159. Moderate protection from the effects of artillery fire is afforded by an earth banquette on the inside of a wall, to a degree depending on its height; the depth of trench supplying the earth adds to the cover for the defenders, though not to the support of the wall.

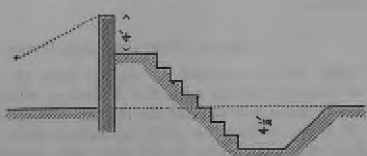


Fig. 109.

The accompanying woodcut (Fig. 109) represents a type of this method of protection, followed by the Prussians in their investment lines round Paris in 1870-71. As a rule, no loopholes were made, and consequently there was nothing to indicate to the French that any particular wall so prepared was occupied for defence. The defenders in the trench were considerably protected from the fire of the *heavy* guns in the French forts.

160. Figs. 110—112, Plate XII., give an example of the deliberate preparation of a wall to be held against a fire of field artillery. In this case a bank of earth, 5 feet in height, is formed in front of the wall, but separated therefrom by a ditch V-shaped, and 5′ or 6′ in depth; another ditch, of a similar section, is made in front of the embankment to afford earth for the latter.

The defenders fire from a banquette, the earth for which is obtained from the trench in rear, which also affords good cover to men sitting in it. The mode of preventing an enemy closing on the wall, and also the head cover to the defenders manning the wall, require no further allusion.

The ditches in front of the wall, on each side of the embankment, are shown as flanked by Gatling guns. If no wall suitable for such a flank exists, a stockade may be made for the purpose. It will be understood from the illustrations that the flanking wall is prepared for two tiers of fire, as it is not itself exposed to a frontal fire of artillery; and it is important to obtain as much fire as possible from a short flank.

Loopholes on Parapets, Tops of Walls, Etc.

161. Whenever men fire over the top of a parapet, or defended wall, &c., they are only covered, while firing, to the height of 4½ feet; therefore, when the banquette is manned for defence, the heads and shoulders of the defenders are visible from the front. It is not practicable to protect men manning a parapet entirely from artillery fire, but it is desirable to afford them protection from musketry and splinters of shells. Loopholes of sandbags, &c., are used for this purpose.

A Sandbag Loophole (Figs. 103—106, Plate XI.) is made with 4 sandbags, as shown. One bag is used for each side; they are laid on the top of the parapet, or surface fired over, 3″ apart in front, and 10″ in rear. A single bag for the roof would not be musket proof. The bag that crosses the inside opening of the loophole requires propping underneath by a piece of stick, &c., to prevent its sinking. For dimensions, &c., of sandbags, see Art. Revetments.

A Log Loophole is shown in Fig. 107. Here a line of logs or trunks of trees is supported about 3″ above the top of the parapet. Greater obliquity of fire is permitted with this arrangement than with sandbag loopholes.

A Brushwood Loophole is shown in Fig. 108. It is used by being embedded in the crests of parapets, with the small opening outside.

A similar loophole may be made by nailing together, so as to form a frustrum of a square pyramid, four pieces of plank, 2′ long, 10″ and 5″ broad respectively, at the ends. The apertures will be about 8″ and 3″ square.

Many other expedients for loopholes may be resorted to. Small boxes filled with earth may be placed on the parapet, with loophole intervals between them. In the Paris barricades, in 1871, pillow-cases were freely used for sandbag loopholes.

Hedges Prepared for Defence (Plate XII.).

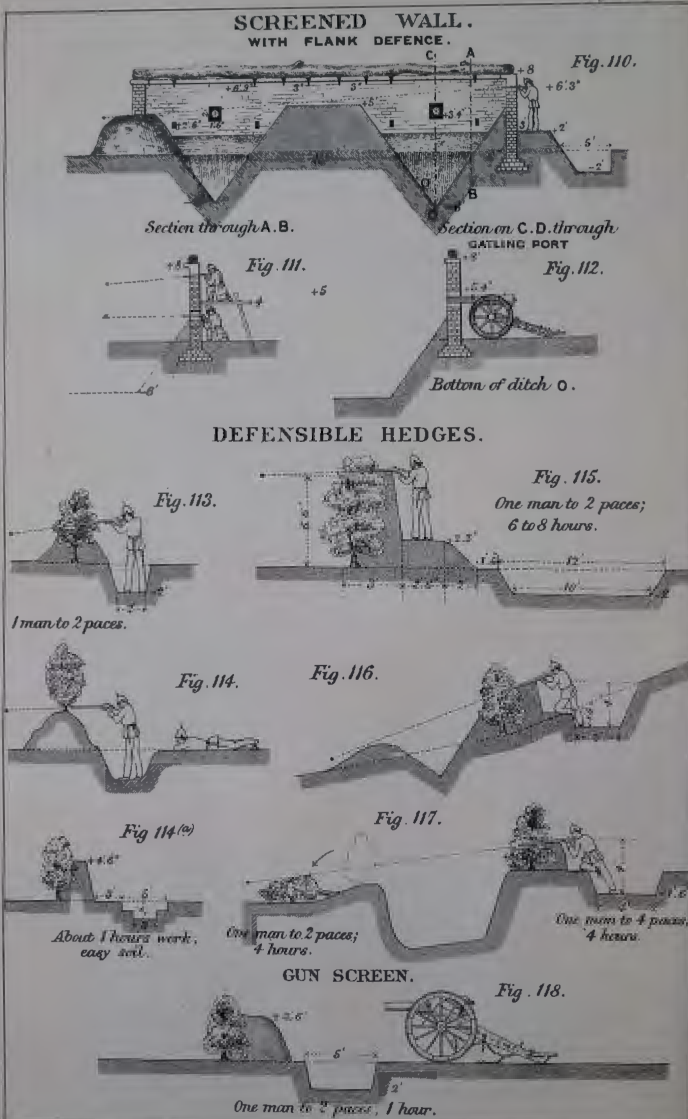
162. *Hedges occupied for defence* have the advantage of being an obstacle to an assailant closing with the defenders, while at the same time the latter can generally manage to see and fire through them without being themselves seen.

A hedge, growing by itself, without a ditch on either side, may be treated in various ways, according to the time and means available for work.

Half-an-hour's work would suffice for a line of men to dig the trench shown in Fig. 113, and bank up the excavated earth against the hedge: the bottom of the trench serves as a banquette.

A hedge with a small ditch *on the inside*, as shown in Fig. 114, is usually available without any preparation, beyond getting rid of any water that may be in the ditch.

163. One to two hours' work would be sufficient to carry out the mode of defence shown in Fig. 114 (a), Plate XII.


SCREENED WALL.
WITH FLANK DEFENCE.
Fig. 110.
Section through A.B.
Section on C.D. through GATLING PORT
Fig. 111.
Fig. 112.
Bottom of ditch O.
DEFENSIBLE HEDGES.
Fig. 113.
1 man to 2 paces.
Fig. 115.
One man to 2 paces; 6 to 8 hours.
Fig. 114.
Fig. 116.
Fig 114(a)
About 1 hours work, easy soil.
Fig. 117.
One man to 2 paces; 4 hours.
One man to 4 paces; 4 hours.
GUN SCREEN.
Fig. 118.
One man to 2 paces, 1 hour.

Here the defenders stand on the natural ground when firing: they may be kept under cover, when not required to fire, by sitting in the trench, either on the steps, or, if necessary, on the bottom. When six or eight hours are available for work a larger parapet may be made, as in Fig. 115, the earth for which is obtained from the trench in rear. If required to afford more cover against artillery fire, the trench may be made narrower and deeper.

Fig. 116 shows a mode of preparing for defence a hedge on ground falling steeply to the front. The front ditch is merely for the purpose of preventing an enemy making use of the hedge; but it is no more indispensable in this case than in those referred to in Figs. 97—100.

Fig. 117 explains a method of occupying a line of sunken road or lane (running in a suitable direction) with a hedge on each side. The sunken road is treated as a *ditch:* the hedge behind is occupied for defence, with a trench parapet; the hedge on the front, or enemy's side of the road, being cut down and *entangled*, so as to add to the obstacle and clear the view of the defenders.

Fig. 118 shows how to prepare a hedge so as to act as a screen and revetment to a gun epaulement.

Hasty Intrenchments.

164. The long range, extreme accuracy, and great rapidity of fire of the rifled arms of the present day render it more than ever necessary that cover should be provided for troops in action.

Cover is required for all troops within range of the enemy's projectiles: for the shooting line as well as for the supports and reserves. Nearly all ground will naturally afford a good deal of the necessary protection, if not in a form that can be at once used, at any rate in a form that can be readily adapted for use.

Supports and reserves, for instance, can be screened and sheltered behind undulations of the ground, woods, embankments, cuttings, &c.; and men firing can be concealed behind hedges, walls, banks, and in ditches, *if such happen to be in the right place:* in most cases such natural cover will require adapting to the exigencies of the case.

During the cannonade, which is the preliminary of most engagements in which guns take part, the defenders are under the fire of shrapnel and common shells fired at long ranges. When the enemy's infantry closes, their artillery fire must cease, and infantry fire at short ranges takes its place.

For the shooting line, therefore, such cover is required to give some shelter from the distant fire of artillery, and to admit of the free use of weapons from behind it. The cover must also be capable of being obtained quickly, as time may be, and often is, the ruling condition.

Earth cover is suitable alike to the most hasty and the most deliberate fortifications. A shallow trench of very small dimensions with the earth thrown to the front will quickly afford cover to men lying in it against artillery fire; and if the mound of earth or parapet be of suitable height the defenders can fire over it when requisite, whilst the whole will present no obstacle to the advance of any troops over it, should such be desired, when an *active* defence is intended.

Trenches of the class referred to are called *Shelter Trenches*: they form the bulk of the fortifications of ground prepared for active defence, being no obstacle to a forward movement, while they may also be used for the *passive* defence, when time for preparation is short: in the latter case obstacles in front would be used.

165. *Shelter Pits.*—Figs. 121, 122, Plate XIII., give the plan and section of a shelter pit for one man, which can be made in about 10 minutes.

The trench is 6′ long (from front to rear) and 2′ 3″ broad: it is 3″ deep in front and 9″ deep in rear. The earth thrown to the front to act as a parapet is made 1′ 3″ in height except on the line of fire, where it is kept 1′ in height. The berm of 4″ affords a rest to the elbow in firing.

In this pit a man fires lying on his stomach, in which position his legs are usually inclined to the left. If to admit of this the pit at first be made at an angle to the line of fire, the legs are exposed; but when made direct as in plan, the legs are protected; if time afterwards be available, it can be improved as shown by dotted lines to suit the inclined position.

A short length of trench of similar section is suitable for groups of two or more men, allowing 2′ 6″ per man.

166. *Shelter Trenches.*—Figs. 123–4–5, Plate XIII., are sections of the *Service Shelter Trench.* Fig. 123 shows the trench that can be executed in half-an-hour by men extended at 5 feet (two paces) intervals. It is 2½′ broad and 1½′ deep, and is the smallest trench that fulfils the required conditions. The earth is thrown to the front, leaving a berm of 1′ 6″, the parapet being kept at a height of 1′ 6″. A row of men kneeling in this trench fire over the parapet.

The above trench can be widened out to 5 feet in half-an-hour, or one hour in all. This is shown in Fig. 124. This may be considered an effective trench for occupation for a limited time, but as the troops in it are in a constrained position, it is desirable, time permitting, to widen it.

In Fig. 125 the above trench is widened to a total breadth of 8 feet. This would require an extra hour's work, two hours in all, and would enable men to lie down in it, and also to fire from it kneeling. The parapet is kept at the height of 1′ 6″, and becomes thicker with each successive widening of the trench.

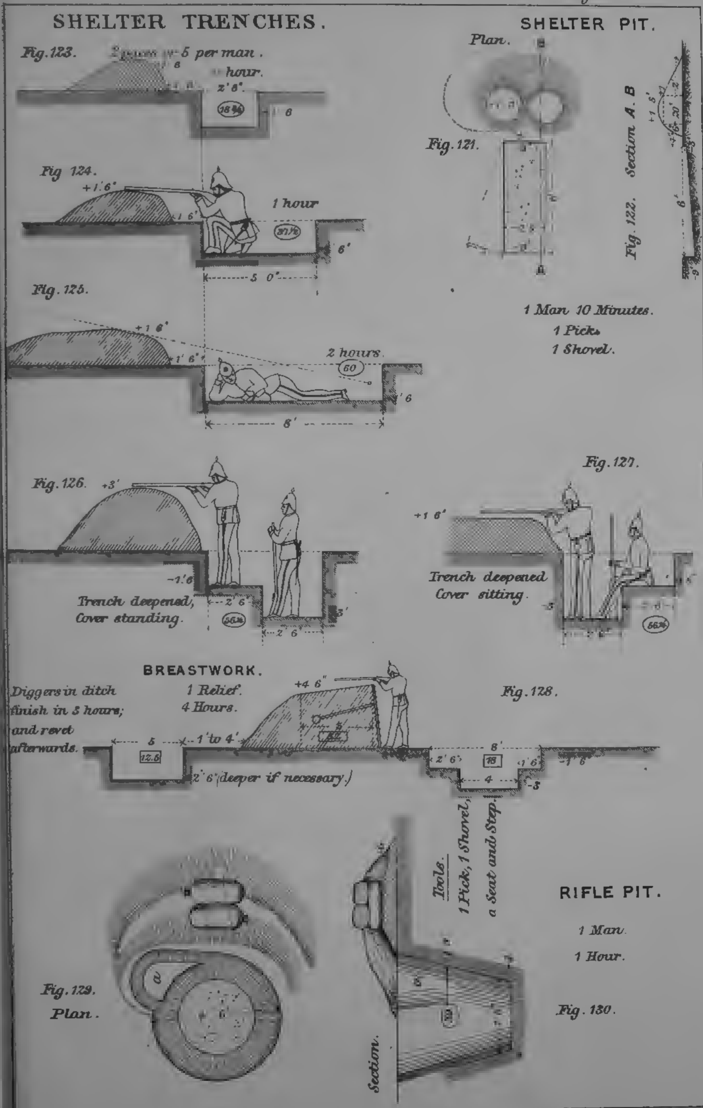
As the main object of shelter trenches is to cover the shooting line, their position must be such that the foreground is visible from the defenders. When occupying rising ground they will not therefore be at the top of the rise, but more usually they will follow the contour *at the top of the steepest portion of the slope*, and need not, therefore, be in straight lines, but only approximating thereto.

167. *Shelter Trenches Modified.*—Fig. 126 shows the rear portion of the *one-hour* shelter trench (Fig. 124) deepened by 1′ 6″, making the depth in rear 3′. This is more convenient for the defenders. It enables men to be under cover either (1) standing in rear, as shown, or (2) sitting in front, while they can fire over the parapet (3′ high) when standing in front. This trench is no impediment to a forward movement of *infantry*, but it is an obstacle to artillery, and, to a certain extent, to cavalry also.

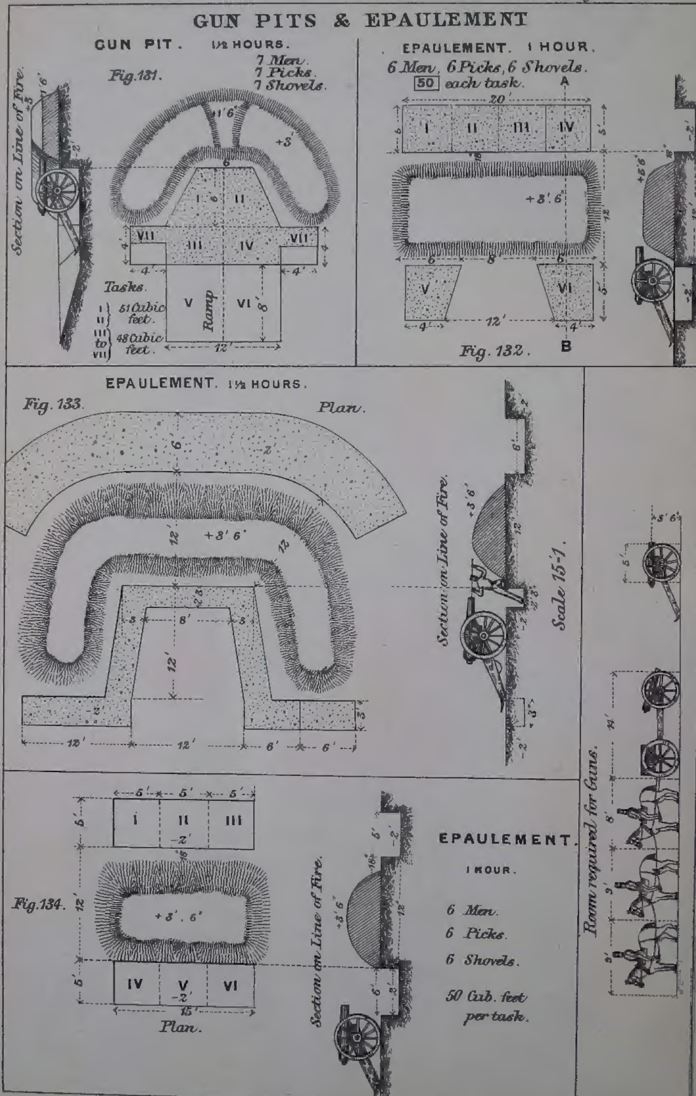
Fig. 127 is another modification of the *one-hour* trench, by deepening the front portion of the trench, and thickening, without heightening the parapet. In this case, the defenders sitting in rear are under cover, and can stand on the bottom of the trench and fire to the front. As an obstacle, it is similar to Fig. 126.

168. *Shelter Trench converted into a Breastwork.*—When a greater amount of cover is required, together with a thicker parapet than is afforded by a Shelter Trench, the modification shown in Fig. 128 may be resorted to, provided four or five hours are available for work and a passive defence only is intended. In this example, the parapet is cleared away towards the front so as to leave a berm, to act as a banquette, 3′ wide. The 8-feet, or *two-hour* shelter trench, shown in Fig. 125, has its central portion 4′ broad deepened by 1′ 6″ so as to leave a step in rear 1′ 6″ broad, and another in front 2′ 6″ broad: this is done by one row of men. A second line of men (both lines at 5′ intervals) excavate the ditch, 5′ broad and 2½′ deep, and thicken the parapet: the interior slope of the parapet would be revetted roughly with hurdle work, or with the clods obtained from the excavations. Except in works of the most pressing nature, it is always desirable to cut the surface turf (if any) into sods, more or less regular, and to use these for revetting purposes. But however simple such an operation may appear to be, it is not easy to carry out, with untrained men, working under difficulties and pressed for time.

169. *Rifle Pits* (Figs. 129, 130). Good cover for advanced sentries is afforded by these pits, which are much used at sieges to cover men in advance, acting both as sentries and marksmen. Opportunities for their use will constantly arise in field defences.



SHELTER TRENCHES.
Fig. 123.
5 per man.
hour.
Fig 124.
+1' 6"
1 hour
37½
6'
5 0"
Fig. 125.
+1 6"
2 hours.
60
8'
Fig. 126.
+3'
-1' 6
Trench deepened,
Cover standing.
2' 6
56¾
3'
SHELTER PIT.
Plan.
Fig. 121.
Section A. B
Fig. 122.
1 Man 10 Minutes.
1 Pick.
1 Shovel.
Fig. 127.
+1 6"
Trench deepened
Cover sitting.
56¾
BREASTWORK.
Diggers in ditch
finish in 3 hours;
and revet
afterwards.
1 Relief.
4 Hours.
+4 6"
Fig. 128.
5
12.5
1' to 4'
2' 6" (deeper if necessary.)
8'
2' 6
18
1' 6
4
-3
Tools.
1 Pick, 1 Shovel,
a Seat and Step.
RIFLE PIT.
1 Man.
1 Hour.
Fig. 129.
Plan.
Section.
Fig. 130.


GUN PITS & EPAULEMENT
GUN PIT. 1½ HOURS.
7 Men.
7 Picks.
7 Shovels.
Fig. 131.
Section on Line of Fire.
Tasks.
I } II } 51 Cubic feet.
III to VII } 48 Cubic feet.
Ramp
EPAULEMENT. 1 HOUR.
6 Men, 6 Picks, 6 Shovels.
50 each task.
Fig. 132.
EPAULEMENT. 1½ HOURS.
Fig. 133.
Plan.
Section on Line of Fire.
Scale 15'-1.
Room required for Guns.
Fig. 134.
Plan.
Section on Line of Fire.
EPAULEMENT.
1 HOUR.
6 Men.
6 Picks.
6 Shovels.
50 Cub. feet per task.

A conical pit 4′ deep, $4\frac{1}{2}'$ in diameter at top and $2\frac{1}{2}'$ at bottom is first excavated, the earth being thrown to the front and as far as may be necessary towards the sides. A sandbag loophole is formed in front, the parapet at that part being levelled off at a height of six inches (see Art. 161, Sandbag Loophole), and a step which also acts as a seat, (*a*) Figs. 129, 130, is cut on one side of the pit at the front. In favourable soil one man will make one of these pits in an hour.

Cover for Field Artillery in Action (Plate XIV.).

170. Field guns in action, like the shooting line of infantry, must be posted in positions where their fire is the most effective, and where the ground in front can be seen.

The limbers with the teams are usually about 20 yards in rear of the guns.

The wagons which supply the limbers may be placed much further to the rear, and can generally make use of existing cover.

In all cases it is desirable not to interfere with the mobility of field guns: this is done by arranging the cover afforded, so as not to interfere with the guns being *limbered-up*, and advanced or retired as may be desired.

171. *Cover for Guns* is obtained either by sinking them in a pit (*gun pit*), or by covering them with an epaulement (*gun epaulement*).

Gun pits afford the same amount of cover in a shorter time than gun epaulements: with this exception, the advantage is with epaulements in which the gun is worked on the ground level; and fires from a height of $3\frac{1}{2}$ feet above it, which affords a better view of the foreground; besides which the gun can be brought into action at any moment, even during the construction of the epaulement, which, if necessary, may be proceeded with while the gun is in action, while a gun pit must be finished before it can be occupied, and is always inconvenient in wet weather or on marshy soil.

In either case the main object is to shelter the gun detachment while allowing the gun to be worked easily.

A pick and shovel are carried on each gun-limber and wagon to allow the gunners to make their own pits.

Gun pits and gun epaulements may be arranged at intervals of 25 to 30 yards: the ordinary intervals between guns in action on open ground being 19 yards.

172. A *gun pit* is shown in Fig. 131, Plate XIV. This can be executed by seven men in one hour, the men arranged as shown by the Roman numerals. The pit is 2′ deep, with a slope or *ramp* to the rear of 1 in 4 to enable the gun to be easily moved in or out. The small side trenches assist in supplying earth for the parapet, and give cover for men, and, if necessary, for a limber-box in each. The parapet is made 3′ high, except on the line of fire where it is kept $1\frac{1}{2}'$ high, or $3\frac{1}{2}'$ above the bottom of the trench.

Fig. 132 shows a *one-hour* gun epaulement made by six men: in this case the gun is worked close to the parapet, the men loading standing on the ground. The parapet is made $3\frac{1}{2}'$ high.

Fig. 134 shows another *one-hour* gun epaulement suitable only for protection from frontal fire. Men in the rear trench, similarly to those in Fig. 133, can load the gun.

Fig. 133 shows a more perfect gun epaulement, giving, in *one and a half hours'* work, protection from both frontal and oblique fire, to the gun and to the gunners.

Works of a more solid nature than this would cease to be considered as "hasty" intrenchments.

173. Gun pits may at times be placed closer together than before described, say, at central intervals of 30 feet. They may then be converted into a battery with a continuous parapet by being connected by trenches 4 feet broad and deep: in these connecting trenches recesses may be formed to hold ammunition.

CHAPTER II.

OBSTACLES.

Uses of obstacles; conditions to be fulfilled; descriptions of PALISADES.—FRAISES.—MILITARY PITS.—CROWS' FEET.—ABATIS.—ENTANGLEMENTS.—DITTO OF WIRE.—CHEVAUX-DE-FRISE.—IRON BAND TRIP.—FOUGASSES: *Common, Shell, Stone, and Self-acting.*—INUNDATIONS, *Dams, and Waste Weirs, etc.*

174. It was remarked in the preceding Chapter that the ditches of field works formed, by themselves, a very imperfect obstacle to the advance of an assailant, who when in them was hidden from the view of the parapet in front, and might (if the ditches be *unflanked*, as is usually the case) assemble in them in greater or less numbers, and rush into the work in a mass. This is to be avoided on the part of the defence, by all possible means; and is usually done by placing obstacles in the way of the advance of an assailant, in such a manner that the closer he gets to a work, and the more accurate and deadly becomes the fire he is exposed to, the slower should be his progress and the more helpless he should become; so that, should he penetrate at all into the work attacked, it shall only be in small numbers *at a time*, and not *en masse*.

175. The chief objects to be attained by the use of obstacles are—

1. To detain an enemy under the close and accurate fire of the defenders.
2. To break up his formation for attack and prevent his advance as a body.

As regards the first of these two objects, *close fire* is considered to be any range within 300 yards.

Obstacles used in conjunction with field works are generally placed in advance of the ditch, as an enemy is thereby detained under close fire and in a position visible to the defenders; but the ditch itself is a suitable position for certain obstacles, as will be referred to.

176. An efficient obstacle should fulfil the following conditions:—

It should be under close fire.
It should be protected from an enemy's artillery fire.
It should not afford cover to an assailant.
It should be so strong, as not to be cut down or removed, without great difficulty.

The principal obstacles which have been hitherto adopted will be described separately in the following paragraphs; and their respective merits detailed.

Although treated singly, they would be used in conjunction with one another, whenever time and circumstances permit.

PALISADES.

177. *Palisades*, Fig. 135, Plate XV., are a stout description of paling, vertical or nearly so, made of large branches of trees, logs of timber, or young trees, split or sawn into two or more pieces according to their size, pointed at the top, and secured to two horizontal bars, or "ribands."

The posts, about 10 feet long, are often made triangular in section, each side being about 8″, and are placed about 4″ apart, their lower ends being spiked to a riband, and planted in a narrow trench 3′ deep. The trench is filled with earth, well rammed, and an upper riband is nailed on the *inside* of the posts about 1 foot below their tops.

An expeditious way to construct a palisade is to prepare, and plant it in panels of 9 or 10 posts.

Palisades are used for the defence of ditches, and for closing the gorges of field work, and in positions generally screened from artillery fire.

Abatis (Plate XVI.).

182. An *Abatis* is one of the best obstacles that can be made. It is formed of stout limbs of trees, or the trunks of small ones, 12′ or 15′ long, laid as close together as possible, with the branches towards the enemy. The abatis should be at least 5′ high, with the butts secured firmly to the ground, either by stout stakes or by logs of timber laid across several butts and secured to them. The small branches and leaves should be removed and the large branches pointed.

Abatis is usually placed in advance of the ditch in a trench dug for the purpose, the earth from which is used as a glacis in front, as in Fig. 141, where every part is exposed to musketry fire.

Where timber is very plentiful, abatis may be formed in thick belts (as was done round Paris in 1870-1) without any covering glacis; it then becomes an almost impenetrable obstacle.

It may also, as in Fig. 142, be placed in the ditches of field works in an upright position, when it forms a serious obstacle to an assault, and detains an enemy outside the ditch.

The labour required to form an abatis depends principally on the distance that the trees have to be dragged after being felled. As the boughs are of course on them, if the distance be great the labour becomes extreme; therefore, the construction of an abatis should seldom be attempted unless the trees grow near at hand.

Hard and tough woods are the best to use, pine being the worst, as it is easily broken, and burns readily even when freshly cut; the boughs often grow perpendicular to the trunk, and cannot, therefore, be made to point towards an enemy.

An abatis, even when exposed to view, is not easily destroyed by artillery fire.

Entanglements.

183. *An Entanglement* is formed by cutting trees, brushwood, &c., half through, above 3 feet above the ground, bringing the upper parts to the ground, and interlacing and securing them by pickets. Large trees thus treated form almost insurmountable obstacles. The ends of thick branches should be pointed, and all weak places strengthened by ordinary abatis.

184. *A Wire Entanglement* (Fig. 143, Plate XVI.) is formed by driving into the ground strong stakes in rows arranged chequer-wise, so as to form a series of equilateral triangles, the sides of which are 6 or 7 feet. The stakes should project about 18 inches above ground, and should be connected together by stout wire twisted round their heads. Roughly speaking, 3 feet of wire is required for each square foot of entanglement. This obstacle should be at least 10 yards broad.

Its defensive value will be much increased if stakes are driven in the centres of the triangular spaces, and afterwards pointed.

No. 14 B. W. Gauge is a convenient size of wire to adopt: a mile of it weighs about 90 lbs.

This obstacle is rapidly prepared, is very portable, little injured by artillery fire, and impassable by cavalry.

185. Another form of wire entanglement is shown in Fig. 144, Plate XVI. The stakes in this case are 4 feet above ground; the head of one stake is connected with the foot of that diagonally opposite by stout wire; these diagonal wires are again connected by thinner horizontal ones, thus forming a network exceedingly difficult to cross.

Iron Band Trip.

186. The bands of Jones' iron gabions may be formed, as in Fig. 146, Plate XVI., into a network or entanglement as an obstacle against Cavalry, and even against Infantry in night attacks.

The bands are buttoned and placed in lines 3 or 4 feet apart; each band is connected with the next in the same row, with stout wire or rope passed through the bridging holes. The rows thus connected are arranged chequerwise, and are connected together at intervals by wire or rope, and secured to pickets driven into the ground.

Chevaux-de-Frise.

187. A pattern of *chevaux-de-frise* forms an article of store. The barrel consists of a hollow iron tube, 6 feet long, with holes through it at intervals for the spears. The latter, 12 in number, are 6 feet long, and pack inside the barrel. Each length of barrel, with its spears, weighs 86 lbs.

Chevaux-de-frise can be improvised from iron pipes, about 5″ or 6″ diameter, or stout beams 8″ or 9″ square, having pointed spears passed through holes bored in them. The spears should be 6 feet long, and not more than 6 inches apart. They should cross at right angles, and should be strong enough to prevent a man breaking them. *Chevaux-de-frise* are made in lengths of from 6 to 10 feet; different lengths being secured together by chains or wire.

Chevaux-de-frise are generally employed as temporary barriers to close the entrance into a work, or through a barricade; to block up a road or street, &c., as in these positions they can be easily moved aside when the communication is required to be used.

Their defect is in the amount of skilled labour required in their construction, which prevents their being used except in small quantities for the above limited objects.

188. *Pointed Stakes*, which can be made in great numbers when any of the foregoing obstacles are constructed, are very useful to occupy as an obstacle ground in front of a work requiring them.

The berm, bottoms of ditches, ground in front of counterscarp, intervals between military pits, the triangular spaces of a wire entanglement, &c., are all suitable positions.

After being driven into the ground they should be sharply pointed.

Fougasses.

189. *Common Fougasses* are small mines, of which the shafts or pits are from 3 to 10 feet deep. The charge of powder is formed thus :— $\frac{1}{10}$ L L R^3 = charge in lbs. L L R means *line* of *least resistance*, and in an ordinary mine is the depth of the charge. The charge of a 6-feet fougass will therefore be $\frac{6^3}{10}$ = 21·6 lbs.; and that for a 10-feet fougass will be $\frac{10^3}{10}$ = 100 lbs. In most cases it is preferable to have many small fougasses rather than a few larger ones. The above charges will make a hole in the ground, the radius of which is equal to the depth of the charge.

The powder is placed in a cubical box, which should be well tarred to protect it from damp, and is lodged in a recess called *the chamber*, on one side of the shaft at the bottom. It is fired by electricity, or by *powder hose* and *fuse*.

190. *A Shell Fougass*, Figs. 148, 149, Plate XVI., is formed by partitioning a box horizontally: loaded shells, with their fuses downwards are placed in the upper part; in the lower part is a charge of powder, with the hose arranged for firing it. The charge should be sufficient (as in Art. 189) to form a proper *crater*, and to blow the shells to the surface of the ground, at the same time that the fuses are lighted.

191. *Self-acting Fougass, or ground torpedo.* Fig. 147, Plate XVI., is an example of this contrivance, and was much used by the Confederates in the American Civil War. A loaded shell was fitted with a wooden fuse case, which contained a patch of detonating composition. The wood plug fitting loosely into the fuse case is retained in position by a safety pin which passes through it. Over the fuse and preserving it from the weather is a cast-iron cup.

The shell was buried so as just to conceal the iron cup, which was placed on the wood plug after the safety pin had been removed. A small red flag was placed to indicate the position of each shell, and was removed when an attack was imminent.

The fuse exploded in a pressure of 7 lbs. to the square inch; consequently, when the cup was trodden upon, the shell burst.

The repulse of the Federals at Fort Darling, on the James River, was ascribed to the use of these fougasses.

Stone Fougass.

192. *A Stone Fougass*, Fig. 149, Plate XVII., is intended to throw a shower of stones against an advancing enemy. It is thus formed:—

An excavation, the axis of which is inclined about 40° to the horizon, is made 6 to 8 feet in depth. At the bottom is placed a charge of powder in a box, a wooden shield, 6 inches thick, is placed on the top, over this shield 3 or 4 cubic yards (about 4 or 5 tons) of stones or bricks are placed; the earth from the excavation is built up over the charge, as at "*a*," to increase the resistance in an upward direction, and to insure the effect taking place in the proper direction—viz., the axis of the excavation. The side of the excavation over the charge will frequently require to be revetted.

The Fougass shown in Fig. 149, charged with 80 lbs. of powder, would throw 5 tons of stones over a surface about 160 yards long, by 60 yards on either side of the axis produced.

193. Fougasses are usually placed beyond the ditch, and on the approaches to the salients and other weak parts of a work. They should be at least 12 feet in advance of the counterscarp to prevent injury to the latter.

The opportunity for the use of fougasses does not arise unless a position is held for a considerable time.

Inundations.

194. An Inundation is formed by constructing one or more dams across the valley of a stream, so that the water collects on the upper side.

To be unfordable an inundation should be 5 feet deep at its shallowest end; the means available for constructing the dams seldom allow a greater depth than 10 feet at the deepest end,—that is, at the end nearest to the dam.

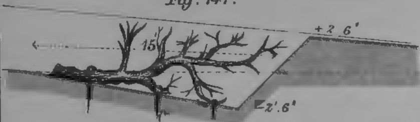
The *breadth of an inundation*, and consequently *the length of a dam*, depends (the depth being assumed) on the slope of the sides of the valley; its length will depend on the fall or slope of the bed of the valley: the most favourable positions for forming inundations are consequently where the bed of a stream has only a very slight fall, and the sides of the valley a regular and rather rapid rise. Where these conditions exist, long inundations may be formed with but few dams; the dams themselves being short.

Where the means available do not allow of the shallow part of an inundation being deeper than 2 or 3 feet, it may be rendered impassable by digging pits and trenches irregularly over the surface, before the water is dammed up. Crows' feet and other obstructions may also be spread over the surface of the ground before the water is allowed to cover it.

195. A Dam (Figs. 150, 151, Plate XVII.) is constructed in the following manner, supposing its position, length, slopes, thickness, &c., to have been carefully determined. The ends are first commenced, and the embankments forming the dam are completed, as shown in the preceding sketches, as far as can be done, *without interfering with the stream*. The waste weir (W W) is also constructed.

OBSTACLES.

Fig. 141.



ABATIS.

Fig. 142.

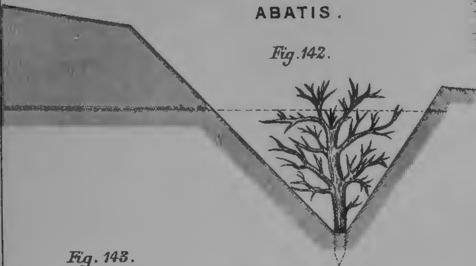
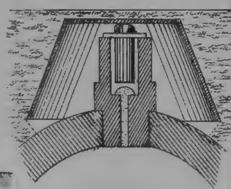


Fig. 147.

Self Acting Fougass.



SHELL.

Shell Fougass

Fig. 148

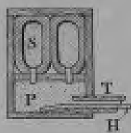
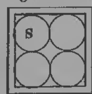


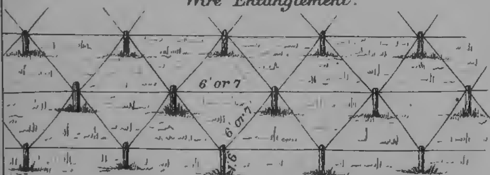
Fig. 149. Plan.



S. Shells.
P. Powder.
H. Hose.
T. Trough

Fig. 143.

Wire Entanglement.



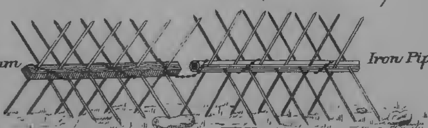
Wire Entanglement.

Fig. 144.

CHEVAUX DE FRISE (IMPROVISED)

Fig. 145.

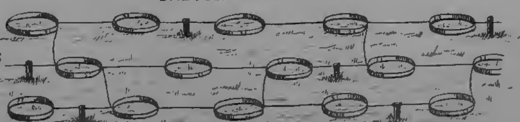
Timber beam



Iron Pipe.

CABION BAND TRIP.

Fig. 146



OBSTACLES.

STONE FOUGASS.

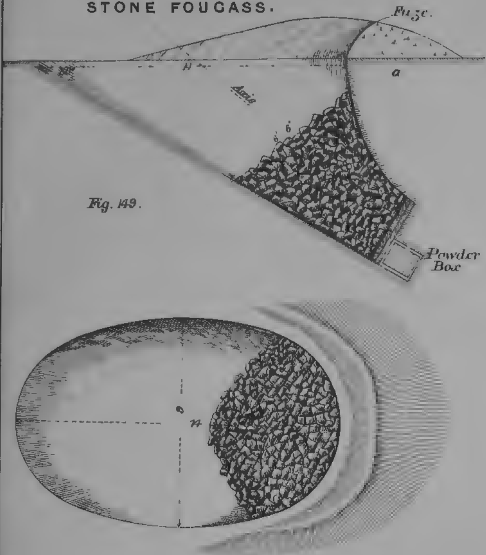


Fig. 149.

Fig. 151.

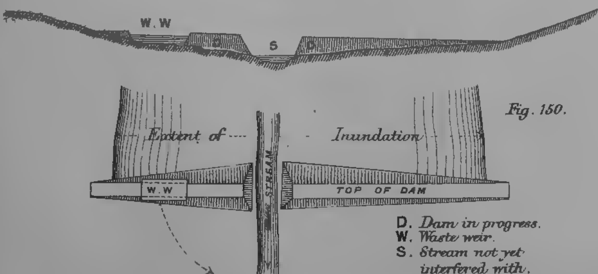
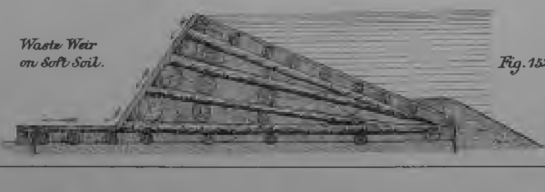


Fig. 150.



Waste Weir on Soft Soil.

Fig. 152.

The soil of the dam should be impervious to water; or if not, a wall of clay or *puddle* should be constructed inside it. The materials for the dam should be taken from the lower side, to increase the depth of the adjacent inundation. Great care should be taken to properly ram the earth forming the dam. The chief difficulty in forming a dam is experienced when constructing the part over the bed of the stream; arrangements must be made to allow of this part being constructed with rapidity, as when once commenced, and the stream dammed up, it must be built up at a more rapid rate than the inundation rises. For this purpose materials will be massed *below* the dam on each side of the stream, and as many men employed as can work together. When everything is prepared, a bank of earth and sods is made across the opening between the two finished portions of the dam, to enable the workmen to commence the foundation of the dam on the bed of the stream; the work is then pushed on with all possible rapidity.

The thickness of a dam at top, as a general rule, may be made equal to the depth of water retained; the upside of the dam, or that nearest to the inundation, has usually a slope of $\frac{1}{2}$, and the lower side a slope of $\frac{1}{1}$. (See Fig. 151.)

When liable to be battered by artillery, the top of a dam should not be less than 10 feet thick.

196. The Waste Weir (Fig. 152), already mentioned, is an opening left in the upper part of the dam, so as to allow the water to flow over on rising to its level. The surface of the weir should be 2 or 3 feet below the top of the dam, according to the liability to sudden floods, and its breadth must be sufficient to allow the water of the stream to pass freely through it. The top and sides of the weir, and also the slope of the dam over which the water runs, together with a part of the bed of the stream on the lower side, must be strongly revetted in order to withstand the action of the current. A double layer of fascines, securely picketed, forms a good revetment for this purpose.

Sluice Gates may also be constructed in dams, whenever required, to allow the inundation being drained.

197. Inundations of the description and extent just mentioned are rarely within the compass of field operations; but frequently a ready means of increasing the obstacles to an enemy's approach will be found in blocking up the arches of a bridge, so as to cause the water to rise on the upper side.

The ditches of Field Works, if they can be flooded, will prove a considerable obstacle. In the case of Bridge Heads, the works can frequently have their ditches flooded by making communications from them to the stream, so as to partially divert the latter through the ditches.

CHAPTER III.

REVETMENTS AND REVETTING MATERIALS.

Object of a revetment; materials used in field works; difficulty of construction; Gabions: *dimensions; mode of making; time, men, tools, &c., required; building in revetments; slope for ditto; iron gabions in use;* Fascines: *dimensions; mode of making; time, men, tools, &c., required; how built in revetments;* Sandbags: *dimensions when empty, and when ready for building with; mode of building a sandbag revetment;* Sods: *dimensions generally used; method of building revetments with;* Casks, Planks, Hurdles, Brushwood and Heather Revetments, Loose Stone Walls *used for revetting purposes.* Addenda: *estimates of quantities of revetting material.*

198. A Revetment is a *retaining wall*, constructed with the object of retaining earth at a slope steeper than it will stand by itself. Permanent defences have their revetments of masonry, but in temporary defences, such as field works usually are, which have to be rapidly built, the revetting materials in general use are *Gabions, Fascines, Sandbags, and Sods;* and when obtainable, *Casks, Planks, Hurdles, Branches of Trees, Heather, &c.*, are made use of.

The formation of the revetments of a work is always a difficult matter, as it involves considerable preparation of material, which requires to be transported to the spot where it is to be used; while the work of building a revetment calls for a considerable amount of skill.

199. GABIONS are cylinders of strong basket work open at both ends, which, when filled with earth, are musket proof, and form good revetments for field works.

Their dimensions are 2 feet exterior diameter, and 2′ 9″ high in the *web*, but they average 3 feet in height when in revetment, in consequence of the projecting ends of the upright rods or *pickets*.

In brushwood gabions the basket work is called the *web*, and the process of making it is termed *waling*.

200. *To make a wicker gabion:* A circle $10\frac{1}{2}''$ radius is first marked on the ground, and its circumference divided into as many parts as there are pickets, the usual number of which is 10; but if the brushwood be small, 12 or even 14 may be used.

The pickets should be 3′ 6″ long, and from $\frac{5}{8}''$ to 1″ in diameter, of oak, hazel, or any sound wood, straight and free from branches: they are driven into the ground touching the inside of the circumference at the points marked, with the thick and thin ends alternately downwards.

The rods for the web should not be thicker than $\frac{3}{4}''$ at the butts; they must be stripped of leaves and twigs, no part of a single rod being used double.

The waling is commenced by placing three rods, as in Fig. 153, Plate XVIII., with their butts or thick ends inside three adjacent pickets. The first rod, which is on the left, is taken up, and passed over the other two, outside the two adjacent pickets and inside the next picket. The second rod, which is then to the left, is then taken up, passed outside two pickets and inside the next one; then the third rod in the same way, then the first one, and so on (Fig. 154). Hence each rod comes in turn to the front, and the web is formed round the pickets. In making the gabion, the web must be continually pressed down with the foot, or beaten with a mallet, and the greatest care must be taken, particularly at the commencement, to preserve the proper diameter. When the web is 2′ 6″ in height, two rods, called *pairing rods* (Fig. 156), are put on at each end to strengthen the gabion; they should be well twisted, and their ends driven down on either side of one gabion picket, at the lowest part of the web, and then passed alternately over and under each other, and inside and outside single pickets, twisting each pairing rod well with the hand during the operation: the ends of the rods are then driven down to the web on either side of the picket *beyond* that at which the pairing was commenced.

The gabion is then pulled out of the ground, turned upside down, and the other two pairing rods put on in a similar manner.

To prevent the pairing rods from slipping off, they are sewn down to the web with four *withes* at each end of the gabion. The withes are rods of hazel, or other good wood, 6 feet long, which are well twisted, so as to open their fibres and allow them to be tied like a rope.

One withe is placed where the pairing rods cross; the other three divide the circumference equally.

To apply each withe: Its thick end for a length of about a foot is forced from the outside through the web about 7 inches from the top, and then bent downwards in its final position; its thin end is then passed over the top of the pairing rods, down inside the gabion, out through the web, near where the thick end entered it (but a rod or two higher up), and hauled taut. It is next passed inwards through the web, about 7 inches lower down, hauled taut, then round the thick end, out through the web two or three rods above where it entered, and hauled taut. It is again passed inwards through the web about 7 inches lower down, and finally fastened off with two half hitches round the thick end, above the point where the last stitch was taken round that end.

As before remarked, each end of the gabion is treated in the same way, but the withes at one end must be in intermediate positions with reference to those of the other, as in Fig. 157, which represents a finished gabion.

The small twigs are trimmed off, and the ends of the pickets cut to blunt triangular points, leaving the pickets 3 feet long. Lastly a *carrying picket* is driven across the inside of the gabion, about the centre of its height, and 9 inches from one side.

Whenever procurable, spun yarn, or iron wire No. 14 gauge, would be used in preference to withes for sewing gabions.

Three men will make a brushwood gabion, with 10 or 12 pickets, in about two hours, one man preparing the rods and withes, one man waling, and the third holding the pickets. If more pickets are used, more time will be required. The tools required for each squad of three men are—1 bill hook, 2 gabion knives, 1 gauge, 1 measuring rod, 1 chopping block, 1 mallet, and 1 grindstone (for several squads), or whetstones in lieu thereof.

The weight of a brushwood gabion will vary, according to the thickness and dryness of the wood used, from 35 lbs. to 60 lbs. The light gabions are specially useful, where they have to be carried under fire (as in flying trench work); the heavy ones, where strong and durable revetments are required, as in the case of batteries.

Gabions are indispensable for revetting purposes generally, and especially so for siege works; but brushwood gabions have the following defects: they are heavy and clumsy to carry by hand; they occupy much space in transport, require much labour to construct, are perishable and very combustible, more particularly in dry weather, and when stored in any numbers.

201. These defects are so well known, and so important, that of late years two kinds of iron gabions have been introduced into the service.

The Sheet Iron Gabion (invented by Captain Tyler, R.E.), is formed of a sheet of galvanized iron, 3 feet wide, and 6 feet 2 inches in length; at each end are three holes, having metal eyes. The sheet being bent round into a cylinder until the eyes at the opposite ends come together, is fastened, in that form, with three pieces of wire. The gabion, thus formed, stands 3 feet high, and 2 feet in diameter; it weighs 26 lbs., and is carried, like the common gabion, by means of a picket passed through it, for which purpose two holes are provided in the iron sheet.

This gabion is durable and incombustible; it is very easily and rapidly put together, and the material (being in sheets) is very portable, and is applicable to many purposes, such as roofing huts, &c. &c. Being, however, without pickets, the sheet iron gabion has but little hold of the ground, and it is difficult to fasten intrenching tools in it; and, as it makes much noise in carriage by working parties, it is unsuitable for secret operations, such as flying trench-work. It also splinters to a dangerous degree when struck by shot.

202. The Iron Band Gabion (Figs. 159—161), invented by Quartermaster J. Jones, R.E., is composed of 10 bands of sheet-iron, each 6′ 5″ in length, and $3\frac{1}{4}$″ in breadth; each band has two buttons at one end, fitting into two holes or slots at the other. Twelve wooden pickets are used with the bands to form the gabion.

To put the gabion together, two men are required. One of the bands, with the ends joined together, is placed edgewise on the ground, thus forming a circle 2 feet in diameter; the pickets are then driven into the ground round the band, at equal distances from one another, and alternately on the outside and inside of the band, and touching it as shown in Fig. 159. The second band is placed on the top of the pickets (taking care that the pickets that were outside one band are always inside the next band fixed and *vice versâ*), and pressed down about half way, as shown in Fig. 160; the third band is then placed on the top of the pickets, the second pressed down on the first, and the third follows the second. The object of keeping the second band halfway, while the third one is being placed on the top, is to preserve the pickets in their places; but after the third one is pushed home there is no necessity for continuing this process. Each succeeding band is placed in the same manner, and the tenth band completes the gabion. No fastenings are necessary to keep the bands on the pickets.

The gabion has been put together in 5 minutes; and could be done with ease in 10 minutes; it weighs 30 lbs., of which the pickets weigh 5 lbs.

Compared with the brushwood gabion, the iron band gabion has the following advantages, viz., lightness, portability (as the bands and pickets are separately packed together), durability, and incombustibility. Moreover, the uninjured bands of damaged gabions can be used to form other gabions.

The principal defect attending them, besides splintering when struck by shot, is that in loose sandy soil the spaces between the pickets and bands allow the earth in them to run through.

Suspension bridges to carry field artillery have been made with these sheet-iron bands, buttoned together as a substitute for ropes or chains, and the inventor proposes to put them to many other uses, such as roofing huts, forming camp bedsteads, military obstacles, &c. &c. (See Gabion band trip, Art. 186.)

202 (*a*). Fig. 158 represents a gabion that has been proposed for use. It is made for a height of about 6 inches at each and by *waling* similarly to that of an ordinary wicker gabion; iron wire netting 2 feet broad being used between. The first 6 inches of waling having been completed and paired, the wire netting is placed on top, each picket passing four times through the net, when the upper portion of web is waled on and paired. The gabion is completed by both ends being stitched.

These gabions are *stiff* and light (16 to 20 lbs.): they are suitable for flying trench work, where men have to carry gabions under fire.

203. A *gabion revetment* (so called) is composed of one or more rows of gabions, with rows of *fascines* (see next Article) underneath each row of gabions. The fascines greatly increase the strength of the revetment.

A gabion revetment to be built up from the ground level is commenced by cutting a groove 3 inches deep along the foot of the intended slope; in this groove a row of fascines is placed, and secured firmly by *fascine pickets* being driven through them into the ground at every yard. The first row of gabions is then laid so as to rest partly on the fascine and partly on the ground in front, as in Fig. 164, also Fig. 162; this arrangement gives the gabions the proper inclination ($\frac{4}{1}$). The gabions are then filled with earth, which is carefully pressed* (not rammed) into them. The parapet is then completed to the level of the top of the gabions, when two rows of fascines are laid on the top of the gabions, picketed, and the earth brought up to the top of these fascines; a second row of gabions can then be placed and filled. By this means a height of 7′ 3″ is revetted. Fascines, sods, or sandbags, as most convenient, can be used for any further small height required.

Figs. 163 and 164 show, in internal elevation and in profile, a slope of $7\frac{1}{2}'$ in height, with a gabion revetment.

The stability of a parapet may be much increased by the employment of anchor fascines or logs of wood, buried in the parapet about 4 feet from the gabions, with which they are connected by rope or wire passed through the web, or between the gabions, and held there by a picket (Fig. 164, Plate XVIII.).

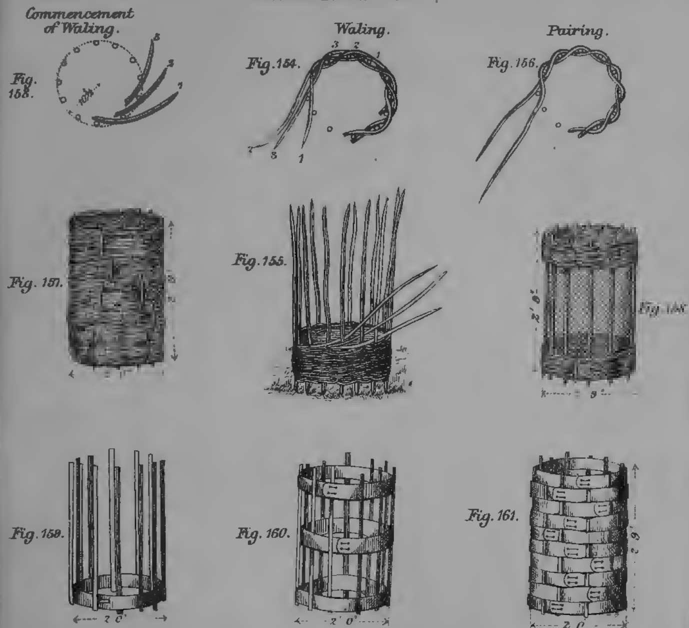
Fig. 162 shows in profile the revetment of the interior slope of a parapet, provided with a banquette; it consists of a row of gabions, with a row of fascines underneath. Two rows of sods are used to *crown* the gabions.

Gabions, in tiers, with a lower and an intermediate course of fascines, form the strongest and most durable field-revetment, and can be used in any soil. They have also the great advantage of not requiring additional men to build them in a revetment, beyond the ordinary working party required to form the parapet; this renders them particularly serviceable for revetting works constructed at a siege.

* The stability of all revetments is greatly dependent on the earth of the parapet immediately behind them being carefully rammed.

GABION MAKING.

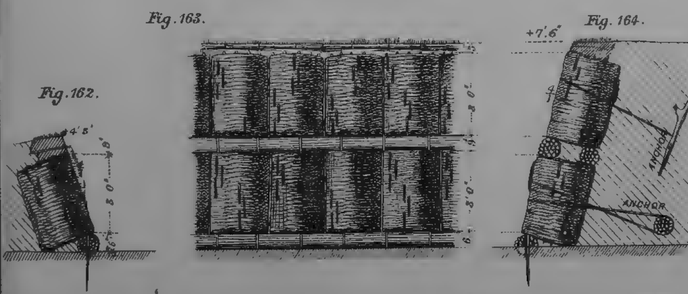
Scale 3 Feet to 1 inch.



The Ironband Gabion (Jones'.)

GABION REVETMENTS.

Scale 5 Feet to 1 inch.



204. Fascines are strong fagots, usually made 18 feet in length and 9 inches in diameter; if shorter ones are required, they are sawn into 6 or 9 feet lengths.

Before fascines can be made, a cradle composed of 5 pairs of fascine trestles have to be set up in the following manner:—Five pairs of stakes, each 6½′ long and about 3″ diameter, are driven obliquely into the ground, crossing one another like the letter X, at 2½ feet above the ground (Fig. 165, Plate XIX.), where they are secured by means of a lashing of 1″ rope. Each pair of stakes forms a trestle. The extreme trestles (Fig. 166) are first set up 16 feet apart; the three others are then set up so as to divide this interval equally, and are consequently 4 feet apart, care being taken that the intersections of the five trestles are in one straight line; this is done by straining a line between the extreme trestles, where the stakes cross.

To make a fascine, brushwood is laid along the trestles, so as to project about 18 inches beyond their extremities, the thick and thin wood being equally distributed in the length of the fascine, and the thick wood kept as much as possible on the outside. When the proper quantity has been placed, the brushwood has to be fastened and secured either by "withes," spun yarn, hoop iron, or iron wire. Twelve fastenings are used to each fascine; they are placed 18 inches apart, the extreme ones being 9 inches from the end of the fascine. By using this number the fascine can be cut into 6′ or 9′ lengths without interfering with the fastenings.

In order to be able to fasten the withes, an instrument called a "choker" (Fig. 167) is used to compress the brushwood to the proper diameter.

The choker consists of a couple of wooden levers 4 feet long, joined with a chain 4 feet long, fixed at 18 inches from the ends. The chain has two small rings on it, 28 inches (the circumference of a 9-inch circle) apart.

To use the choker, the chain is passed once round the brushwood, and the levers are pressed downwards until the rings of the chain meet. A withe can then be tied close to it. The choker is then removed and applied successively to the positions where the other withes are to be fastened, which are tied in succession. The fascine is completed by trimming projecting twigs, and by sawing the ends square at the distance of 18 feet apart.

Spun yarn, or iron wire (annealed), is frequently used in place of withes for the fastening both of fascines and gabions. Wire is the best fastening, and would be used whenever procurable. Two turns of each should be taken round the fascine.

Hoop iron bands may also be used, of the dimensions shown in Fig. 171; the notches are hitched into one another when the band is put round the fascine.

Five men are required to make a fascine; after setting up the trestles, they can make one fascine for each hour they work. The average weight of an 18 feet fascine is about 140 to 150 lbs.

The following tools are required for each squad of five men, viz., 5 pairs of stakes and 5 lashings for the trestles, 1 choker, 1 maul, 1 handsaw, 3 billhooks, 2 gabion knives, 1 6-feet rod, together with 1 grindstone (or several whetstones in lieu) for several squads.

Fascine Pickets, 3½′ in length and 1¼″ or 1½″ in diameter, are provided for securing the fascines, in the proportion of 6 to each fascine.

To make a withe.—The best rods for withes are hazel; they should be 5 feet long, and between three-eighths and three-fourths of an inch in diameter, neatly trimmed, leaving one-eighth of an inch of each branch on the rod. In making a withe, the thick end of the rod is placed under the left foot, and the rod twisted with the hands, from the top downwards, taking care to avoid kinks. When the rod is well twisted at the small end, and moderately so downwards, a loop about 9 inches long is made at the small end, by taking a half hitch with the end of the rod round the standing part (Fig. 168); the loop is then given a couple of twists in the contrary direction, so as to plait the double part of the rod and form a secure loop (Fig. 169); the other end is then pointed, and the withe is complete. As the strength of the fascine depends upon the withes, they must be properly selected and well twisted, particularly at the eyes.

To fasten a withe it is passed under the brushwood, and the ends brought up: the point is then passed through the eye and hauled taut by one man who twists the withe as he does so, and then hands it to the other man (on the opposite side of the fascine) who completes the fastening, as shown in Fig. 170, by twisting it round itself.

205. *In building a fascine revetment* from the level of the ground (Fig. 173), a groove 3 inches in depth is first cut along the line representing the foot of the slope. In this groove the first row of fascines is laid, and fastened firmly to the ground by being picketed thereto; as soon as the earth of the parapet is brought up to the level of the top of the first row of fascines, a second row is laid, care being taken that the joints of successive rows are not over one another. Each fascine is fastened to the row beneath it by two pickets, and to the earth of the parapet by four or five pickets. The other rows are laid in a similar manner.

In revetting with fascines in weak soils, 6′ fascines at intervals may be used as headers and the fascines should be *anchored*—that is, fastened by long withes or by rope to boughs of trees, or stout stakes driven into the interior of the parapet, while it is being constructed. This precaution greatly strengthens the revetment.

Fig. 174 shows an interior slope and banquette for infantry, revetted with fascines.

Fascines are built at a slope of $\frac{4}{1}$.

Revetments formed entirely of fascines are not so strong as gabion revetments, and are much heavier, which is an inconvenience, particularly if the materials have to be brought from a distance. The average weight of a gabion revetment per square foot is from 6 to 7 lbs.; that of a fascine revetment being about 10 lbs. Extra men are also required to build up a fascine revetment. Fascines are requisite, as before shown, as intermediate courses between rows of gabions, where they add much to the strength of the revetment. They are also most useful in revetting steps or similar small heights as in Fig. 174, where gabions would be too high, and they have the recommendation of being made of wood too coarse and large to use for constructing gabions.

Besides being used for purely revetting purposes, they may be employed in place of planks for the superstructure of rough bridges, or for roofing Field Powder Magazines, Caponiers, or for covering Blinded Galleries, &c. &c. They are also very serviceable in forming the rough drains that are required in Field Works.

206. Sandbags are bags of coarse canvas, measuring, when empty and laid flat, 2′ 8″ long and 1′ 4″ broad. They contain when full a bushel of earth; but in building them in revetments they are only three-quarters filled, in order that they may be easily flattened with a spade or shovel into the shape of a brick 20″ long, 10″ broad, and 6″ high; and then weigh from 60 to 70 lbs. each. Tarred sandbags weigh when empty 1 lb. 12 oz. each.

207. *Sandbags are built in a revetment* in rows or *courses*, which are alternately all *headers* or all *stretchers*—*i.e.*, have their ends exposed to view (headers), or their sides exposed to view (stretchers). It is always desirable to finish the revetment with a header course, and therefore it is necessary to commence with a row of headers, if an odd number of courses are required, and with a row of stretchers if an even number are used. The slope at which the revetment will stand is $\frac{4}{1}$.

In building a revetment of sandbags (see Figs. 175, 176), the ground should be sloped away perpendicularly to the slope of the intended revetment, the first row is then laid, the bags touching one another, and in the proper line; the earth is then brought up to the level of the top of the bags at their back and *well rammed*: the second course (headers if the first course was stretchers, and *vice versâ*) is then laid on top of the first course, care being taken to *break joint*, *i.e.*, to keep the junction or *joint* of any two bags in one row not over the joint of the row below. When the earth of the parapet has been rammed up to the level of the top of this row, a third row of bags is then laid similarly to the first, and so on with successive rows, the parapet, or, at least, that part in contact with the revetment, being carried up simultaneously with the revetment. The neck or *choke* of the bags in header rows is laid inside to prevent its unfastening.

Two *builders* can lay 70 sandbags per hour, if well supplied by two *carriers* and one *filler*.

The number of bags required for any particular revetment will be found by taking the number of rows of headers and of stretchers, and by finding the number of bags in each row.

If the header rows are the same in number as the stretcher rows, the required number of bags may be found from the fact that every 3 bags (2 headers and 1 stretcher) will revet 240 square inches (20 × 12), or, *on an average*, 80 square inches per bag. This is at the rate of 18 bags for every 10 square feet of revetment, without allowing for waste.

208. Sandbags have the great advantage of being very portable. When untarred, they are made up in bundles of 125 which weigh 75 lbs., and two men can carry one bundle on a handbarrow.

Gun batteries have been built at sieges entirely of sandbags, which are filled at the nearest convenient site and brought to the place. This may be done either to save time, by employing a great number of men, or else in cases when the earth cannot be excavated on the spot, as in rocky or marshy soil. In this manner whole batteries have been constructed and armed in a single night.

Fig. 175 shows an interior elevation of a sandbag revetment in progress, which is shown in profile in Fig. 176.

The great defect of sandbags is that they are very perishable; if untarred, they will rot in a revetment in two months, or less if the weather be wet.

The formation with sandbags of loopholes on the tops of parapets has been already described in Chapter I, and a similar use is made of them at sieges on the top of the parapets of the trenches.

They are also frequently useful in other ways; as for instance, in sieges or bombardments, to cover over the roofs of magazines, and to repair damages generally, and for that purpose should be kept filled in readiness for use.

209. Sods for revetting purposes are cut usually 18 inches long, 9 inches broad, and $4\frac{1}{2}$ inches in thickness, and when built up in a revetment they *average* only about $2\frac{1}{2}$ inches in height for *ordinary turf sods*, owing to the manner in which they are pared off as successive courses are laid, and to their becoming compressed with the weight above them.

Sods are built in a revetment in a manner similar to that described for sandbags—*i.e.*, the sods are in rows or courses, which alternately are all headers or all stretchers; each course is laid at right angles to the intended slope, with the grass downwards, and the joints of successive courses should be broken. Over each row or course of headers a double row of stretchers is laid; this keeps the revetment (as in Fig. 177) of the same thickness throughout.

The retaining slope of a sod revetment is only $\frac{3}{1}$, as sods are not strong enough to support earth at $\frac{4}{1}$.

The grass should, as mentioned, be laid underneath in building; this allows the earth on the top of each course to be carefully smoothed for the reception of the next course, which can then be laid, and similarly treated; the last course is laid with the grass uppermost, and as headers. Thin deal pegs are used to connect several courses.

Sods form a very neat revetment, and are frequently procurable on the spot; but they require greater labour, and more time to build, than any other kind of field revetment. This renders them unsuitable for siege purposes; but notwithstanding the above defects, they will often be used as a revetment for field purposes.

The requisite number of sods may be estimated from the fact that every 4 sods (2 headers and 2 stretchers) occupy 90 square inches (18 × 5) of revetment; or, on an average, 22·5 square inches per sod. A considerable margin (say $\frac{1}{5}$th) should be allowed for waste, as they are very easily broken by rough handling.

F

210. Casks form a good substitute for gabions in revetments; their ends being removed, they are filled with earth, like gabions. They should not be used in positions exposed to fire, on account of the splinters that would be detached from them if struck by shot.

211. Planks form a very good revetment for interior slopes and for steps, &c., of Field Works. Stout stakes are driven at intervals in the direction of the slope, the planks are placed inside them, and when necessary are anchored.

212. Hurdles for revetments should be made 6 feet long and 2 feet 9 inches high. On a circle of 8 feet radius, an arc of 6 feet long is measured, and 8 to 10 pickets are then driven in at equal distances. The web is made in a manner similar to that of a gabion, excepting that in the hurdle some of the rows of rods are twisted so as to cross each other like a chain, as in Fig. 181, whilst others are laid horizontally, passing alternately within and without each rod; the ends of the rods are secured by being passed upwards or downwards in a similar manner through the horizontal rods. A revetment of hurdles requires to be carefully attached to the parapet at the top by anchoring pickets; the pickets upon which the hurdle is made being driven well into the ground. Three men will make a hurdle in three hours; it will weigh 50 lbs.

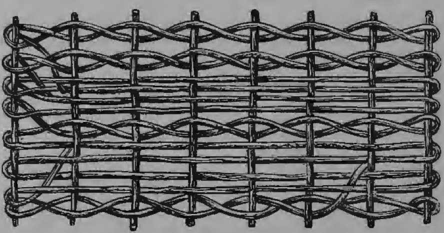


Fig. 181.

A species of hurdle revetment may be formed for the interior slopes of Field Works, by driving in stakes in the direction of the slope, to answer to the pickets of the hurdle, and by working brushwood in and out of these pickets throughout the length of the revetment. This should be well anchored (Figs. 178, 179, Plate XIX.).

The bands of Jones' gabions used in place of the brushwood form a very good and neat-looking revetment.

213. *Brushwood Revetment* (Fig. 180, Plate XIX.).—A simple way of revetting the interior slope of a parapet for infantry is to drive stakes, about 2 inches diameter, 1 foot into the ground at the foot of the slope, at intervals of about 1 foot from one another.

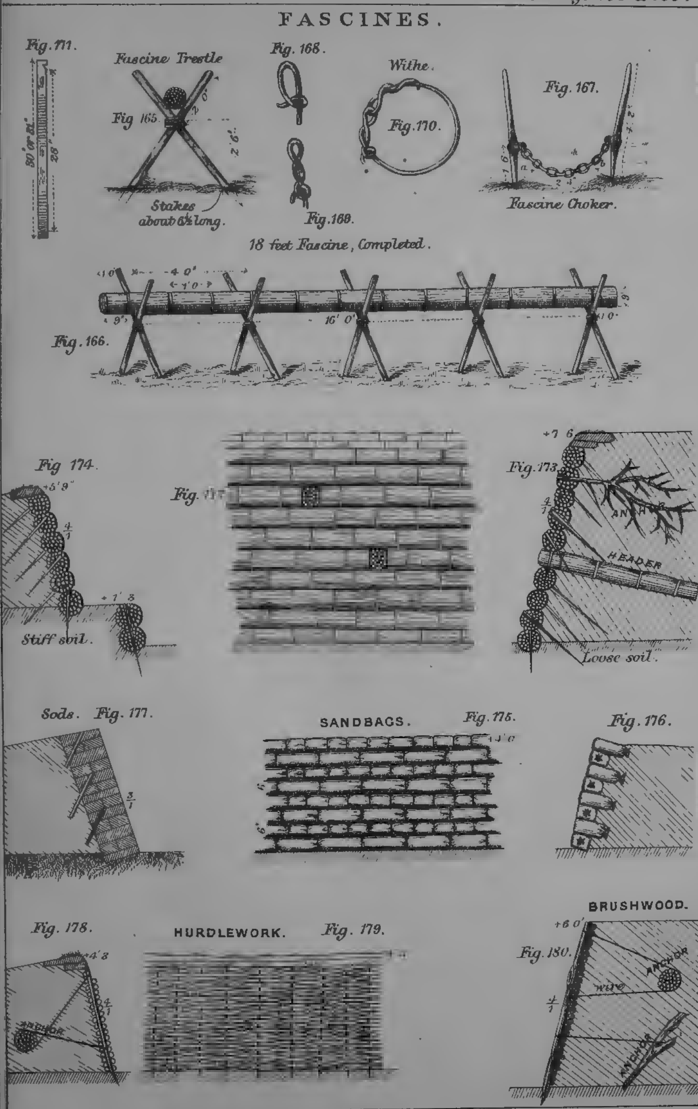
As the parapet is thrown up, rods and small branches are laid between those stakes and the earth, which is thus supported. The stakes should be driven with a greater inclination (*i.e.*, less steep slope) towards the parapet, than that at wihch the revetment is required to stand, and they should be anchored to the parapet, by any available means, to increase the stability of the revetment.

214. Loose Stone Walls are frequently constructed for interior slopes; and when only exposed to musketry fire they may be used by themselves as breast-works, but they should not be employed in positions where they would be liable to be struck by shot, on account of the danger from splinters.

215. Heather, also small *branches of trees*, particularly fir trees, placed in layers, may be used to make very effective revetments for small heights.

A layer of the heather (or other substance used) is laid along the line of intended revetment; it is then covered with earth, a second layer is then

Pl. XIX. *Figs. 165 to 180.*



placed and covered with earth, and the successive layers are laid in a similar manner. At the Royal Military College, Sandhurst, heather revetments made in this manner are used with considerable advantage.

The revetments of all parapets for musketry fire should be finished with either sandbags, sods, or well-rammed earth.

216. Addenda to Chapter III.—Estimates of Quantities of Revetting Materials, etc.

Example 1.—*A breastwork of $4\frac{1}{2}'$ in height, and 50 yards in length, is to have its interior slope revetted with sandbags. How many sandbags would be required, without any allowance for waste, &c.?*

Dimensions of sandbags in a revetment—length 20″, breadth 10″, height 6″.

Height of revetment = $4\frac{1}{2}$ feet, or 54 inches.

As each course of bags averages 6″ in height, there will $\frac{54}{6} = 9$ courses.

As it is always desirable to finish with a header course, we must in this instance, as there is an odd number of courses, commence with a header course; consequently there will be 5 header courses, and 4 stretcher courses.

No. of bags in each header course $= \frac{50 \times 3 \times 12}{10} = 180$

No. of bags in each stretcher course $= \frac{50 \times 3 \times 12}{20} = 90$

No. of bags in all the header courses ... $= 180 \times 5 = 900$

No. of bags in all the stretcher courses ... $= 90 \times 4 = 360$

Total number of bags required ... = 1260

Example 2.—*A parapet $3\frac{1}{2}'$ in height (for field guns to fire over) and 60 yards in length, is to have its interior slope revetted with sods. Required, the number of sods, without allowing for waste, &c.*

Dimensions of sods (turf) in a revetment $= 18'' \times 9'' \times 2\frac{1}{2}''$

Height of revetment in question $= 3\frac{1}{2}$ feet, or 42 inches.

Number of courses of sods in do. $= \frac{42}{2\frac{1}{2}} = 17$ inches.

Length of revetment = 60 yards, or 2160 inches.

Number of sods per course $= \frac{2160}{9} = 240$

Then the number required will be $17 \times 240 = 4080$.

Example 3.—*The infantry portion of the parapets in a redoubt has a length of 180 yards, and is to be revetted throughout with a row of gabions, resting on a row of fascines, and crowned with two courses of sandbags. Required, the numbers of each of the revetting materials for the purpose.*

No. of gabions ... ... $= \frac{180 \times 3}{2} = 270$

No. of fascines ... ... $= \frac{180}{6} = 30$

No. of fascine pickets $= 30 \times 6 = 180$

No. of sandbags, header course $= \frac{180 \times 3 \times 12}{10} = 648$

No. of sandbags, stretcher course $= \frac{180 \times 3 \times 12}{20} = 324$

Total number of sandbags required... = 972

CHAPTER IV.

DESCRIPTION OF FIELD WORKS.

General remarks as to "trace" of works, and to their use as tactical points, when employed for "active" and for "passive" defence. DEFINITIONS: *Salient and re-entering angles, flank, line of defence, angle of defence, outline, gorge, capital, open, half-closed and closed works.* PRINCIPLES TO BE OBSERVED IN DETERMINING THE OUTLINE OF A WORK, *with reference to the length of parapet, shape of work, flank defence, security from enfilade, size of re-entering and of salient angles, length of lines of defence.* REDANS: *their nature, defects, &c.; Double and Triple Redans.* LUNETTES: *their nature, defects, &c.; modes of closing the gorges of open works.* CLOSED WORKS: *redoubts or forts; defects inherent to closed works; most apparent in small works.* REDOUBTS: *their shapes, size, and garrison; defects of redoubts, how remedied or modified; auxiliary flank defence by caponiers and counterscarp galleries; defects of caponiers and galleries, their best situations; entrances into closed works.* BLOCKHOUSES: *nature, object, and suitable situations; how made to resist musketry and artillery.* FORTS: *their general advantages when of proper size; advantages of parapet flank defence for field works.* STAR FORTS: *their trace when regular and irregular; defects of star forts.* DOUBLE STAR FORT: *its advantages.* BASTIONED FORTS *have complete parapet flank defence; construction of a front; lengths of exterior sides; peculiar formation of the ditch of a bastioned front; to trace an irregular bastioned front.* DEMI-BASTIONED FORTS: *their trace and defects; suitable positions.* REDUITS: *their object; various methods of construction.*

217. Whenever increased power of resistance is sought for by means of defensive works, their general plan, called the "*Trace*" must be entirely subservient to the tactical requirements of the case.

The governing or "Magistral" line of the trace in field fortification is that from which the fire proceeds, viz., the "interior crest" of the parapet.

Whilst providing cover for all troops engaged, the arrangement of works must not hinder counter-attack, where such is required; the more "active" the defence, the less desirable is the general use of the stronger profiles, which are obstacles to the advance of friends as well as the entrance of foes. A compromise must therefore be made between the two conflicting conditions of *strong profiles with obstacles*, and *freedom of forward movement*, giving more or less value to either condition as may be most expedient under the circumstances.

218. The principle which best meets all requirements, and admits of expansion or contraction under ever-varying conditions, is to fortify, as strongly as time will allow, at intervals along the line to be occupied, Farms, Villages, &c.; or, in default of these, to construct earthworks of strong profile, within reach of one another's fire, and having troops (with *distinct garrisons*) told off to hold them with more or less obstinacy according to their situation.

The remainder of the troops are free to take up positions between or in rear of these works, furnishing as much fire as may be required over the whole front, and keeping reserves close at hand, ready to reinforce the defender, or to deliver a counter-attack, as the case may be.

The whole of these troops, whether firing, or either in support or in reserve, must be covered as much as possible from the enemy's fire, or at least screened from his view; using and adapting for themselves existing circumstances of the ground, and throwing up shelter trenches, &c., when in the open.

219. Thus the fortified points (called "*supporting points*," or "pivots" of the line) detain the enemy and break his line, enabling the defenders' reserves either rapidly to deliver a counter-attack under favourable circumstances, or to meet on more than an equality, such troops as may manage to press through the intervals.

Obstacles may be freely employed around the "supporting points," but their use in the intervals between them, as well as the character of the cover provided for the manœuvring troops (sometimes called the "*outer*" troops) must depend on the extent to which personal collision with the enemy is courted.

In certain restricted situations, where the defence has a purely *passive* object, and where there is sufficient time, lines of earthen parapet of the stronger profile may in conjunction with obstacles close the spaces between the supporting points, and thus form what are called "continuous lines of fortification."

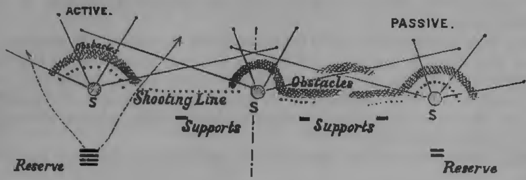


Fig. 182.

Fig. 182 is intended to convey a rough idea of the principles here inculcated, the left side of the diagram being arranged for an "active" defence, the right side for a "passive" defence, S S representing the points occupied as "supporting points."

220. In all the different cases in which field fortifications are intended to cover and assist the action of large bodies of troops, this principle of fortifying "pivots" is adapted, with slight modifications for each case. These are the portions which, with earthworks particularly, require most time to elaborate, and especially call for the services of the Field Engineer. Their trace and general details will be treated of in this chapter, without reference to the shelter trenches and other slighter defences executed by the "outer" or manœuvring troops for their own use.

Definitions, &c. (Plate XX.).

221. A *Salient Angle* is one which points outwards or towards the exterior of a work.

A *Re-entering Angle* is one which points inwards or towards the interior of a work.

A *Flank* (in Fortification) is a line of parapet (or other "shooting line") made for the special purpose of defending some ground or other part of a work by a *flanking* fire; and this latter is then said to be *flanked* by it.

The term "Flank" also generally applies to the extremities of any line, whether of troops, or of works.

A *Line of Defence* expresses the distance, or line, extending from a flank to the *farthest* part of the line flanked by it, as *a b* or *b c*, Fig. 183, or *b d*, Fig. 184.

An *Angle of Defence* is that formed by a *Flank*, and a *Line of Defence*, as *a*, *b*, *c*, Fig. 183, or *a*, *b*, *d*, Fig. 184.

The *Trace* or *Outline* of a work is its general shape in plan. The term is also used to express the plan of only the "*Magistral*" line of a work (crest line in Field Fortification) which is then said to be *drawn in outline*.

The *Faces* of a work are two of its sides which meet in an angle, whether salient or re-entering.

The term is also used to express *any particular sides* of a work, as "right" or "left" face, "side" or "rear" face, &c.

The *Gorge* is a line joining the inner extremities of an open work. (See Figs. 189—194 among others.)

The term *gorge* is also frequently used to refer to the *rear* part of any work, such as a redoubt, &c.

The *Capital of an Angle* is the imaginary line which bisects the angle, Fig. 187.

The *Capital of a Work* is generally used to express the line which (passing to the front or towards an enemy) divides a work into two parts, which in a work of regular shape would be equal parts.

Thus in the six Figs. 189 to 194 the capital of each work would be perpendicular to the gorge line; in each of Figs. 189, 192, and 194 it would pass through the salient angle, in Fig. 190 it would pass through the re-entering angle, and in each of Figs. 191 and 193 it would pass through the middle of the *front face* of the work.

Open Works (Figs. 189—195) are those which have thick parapets only on the exposed sides (usually the front and flanks), the rear or gorge being left open.

Half Closed Works are works similar to open works, but which have the gorge closed by a line of obstacles, or by a thin earthen parapet or stockade.

Closed Works are those which are surrounded by thick parapets and exposed to *artillery fire on every side.**

222. Principles to be observed in determining the outline of Field Works.

1. *The trace should be as simple as possible,* with few faces, and giving powerful frontal fire on the sides most liable to attack; these are usually the front and flanks. (See Figs. 191-2-3-4-5, Plate XV.; also Figs. 196-7-8, Plate XXI.).

2. *The length of firing line (crest line of parapet)* should be proportional to the number of men in the garrison. See Art. 230.

3. The parapets of a work should not only fire in the directions required as stated in (1), but they should be *adapted to, or fit, the ground on which the work is situated.*

This rule implies that when works are on rising ground, as in profile, Fig. 185, and plan, Fig. 186, the parapets should not only fire in the direction required, but should be fixed in positions whence the slopes of ground in their front can be swept by their fire. (See chapter on "Adaptation of Works to Ground.")

4. *There should be a reciprocal defence between all the parts of any system of works,* so that the ground over which an enemy must advance to the attack of any part of the works should be seen in flank from other parts, and therefore exposed to a cross-fire.

This condition is easy to fulfil when several works mutually support one another, as in Fig. 195, Plate XX., or Fig. 196, Plate XXI., but is difficult to fulfil in single works.

5. Flanks must be within effective range of the farthest point in the line they are intended to flank, viz., 300 to 400 yards for rifles, and 1,500 to 2,000 yards for guns.

They ought not to be less than 12 yards long, so as to hold about a dozen rifles, and also in order to occupy the prolongation of a ditch they may defend, as *d e*, Fig. 188, Plate XX.

The greatest length for the line of defence in a single work will seldom be as much as 200 yards.

6. *The faces* or *other long lines of parapet should be secure from enfilade fire,* and should therefore be traced with their prolongations falling on ground inaccessible to the enemy, or, at least, to his artillery.

It is impossible to avoid some lines being enfiladed, especially the side faces (or flanks) of works supporting one another, as their prolongations pass nearly

* The term *Half Closed Work* is of recent adoption in the Service, and is not altogether a satisfactory one; formerly all works were either *Open* or *Closed.* It would seem desirable to define *Open Works* as those having parapets (firing lines) on the exposed sides, the gorges being left open; *Half Closed Works* as open works, with attack by the rear guarded by obstacles at the gorge; and *Closed Works* as works requiring parapets (firing lines) all round; the nature of the parapet depending on its *degree of exposure* to artillery fire as well as that of musketry, or only to the latter.

directly to the front. Especial care is taken to protect these lines from the effect of the enfilading fire; and also they are made as short as is consistent with the object they have to fulfil.

7. *Salient Angles should be as obtuse as possible*, and never less than 60°. A sharp salient, such as that in Fig. 187, has its interior space much contracted, while the sectoral space in front of the angle undefended *directly* by fire becomes greater as the size of the angle becomes smaller.

If it be assumed that soldiers can fire 30° to the right or left of a perpendicular to a parapet (*and it is now laid down that they can do so*), the sectoral space undefended by the faces of a salient angle will be the supplement of that angle, less 60°.

It is, however, always to be remembered that soldiers fire most naturally to their own front, and when a work is attacked, the attention of the defenders is usually directed to what is happening in their own front, from which they are generally being fired at. From this it will result that if the defenders of a salient are firing on an enemy in their own front, the undefended sectoral space will be the supplement itself of he angle.

In any case large salients which face an enemy are better than small ones.

8. *Re-entering Angles* should be from 95° to 100° if intended as flanking anglés; if not, they should be larger.

A flanking angle (for one parapet to flank another, as in Figs. 183, 184, or Figs. 188 and 190) should be larger than a right angle, in order that the fire should naturally tend across the ditch flanked (especially at night, or in fogs or smoke) and on to the ground in advance, rather than towards the defenders of the line flanked. This is requisite in field works on account of their small command and narrowness of ditch, as compared with permanent works where the same rule does not apply.

The above general rules are fulfilled to as great an extent as is possible in the types of works represented in Figs. 191-2-3-4-5, Plate XX., and Figs. 197, 198, Plate XXI.

In all these, the salients are as large as practicable, the outline is simple, and the depth of the work, which measures the length of the side parapets—*i.e.*, those exposed to enfilade—is a minimum.

Redans and Lunettes (Plate XX.).

223. A Redan (Fig. 189) is a work consisting of two faces, or lines of parapet, meeting in a salient angle, the gorge being open. When the faces are not more than about 20 yards in length, it is sometimes called a *flèche*.

The weak points of this work, if unsupported by other works, are that it has the ground in front of the salient undefended (more or less, as the angle is small or large) by *direct fire;* its ditches are entirely undefended, being unseen or *dead;* there is no flank or reciprocal defence; and its open gorge renders an attack there easy, particularly at night.

On account of having an open gorge, it is seldom advisable to construct a redan as an isolated work; it is best calculated for positions where there is some sort of protection or defence immediately in rear—viz., to cover a guard or an advanced picket, as an outwork to look into hollows, or view slopes not seen from the principal works, or in front of a bridge (Fig. 195), dam, road, avenue, or defile.

The first defect—viz., that of having an open gorge—may be remedied in some degree by placing along the gorge abatis, chevaux-de-frise, palisades, or other suitable obstacle; as to the second defect, a direct fire may be brought in front of the salient either by rounding the latter or by filling up the angle so as to form a short face, termed a "pan coupé," not less than six yards long, as $a\ b$, Fig. 188. The pan coupé is usually limited to this length, as there is a loss of fire from *both* faces incurred by increasing it, as from $a\ c$ and $b\ c$ (Fig. 188). The ground in front of the salient should be further strengthened by obstacles, as Fig. 187.

A machine gun at the salient is also most useful.

A flanking fire may be procured for the ditch at the salient by constructing *auxiliary flanks*, which may be placed either at the middle or at the extremities of the faces; these flanks also evidently bring a cross fire on the capital of the work, as *d f* (Fig. 188).

The length of a flank depends on the length and importance of the line to be flanked, but no flank ought, as a rule, to be less than 12 yards long, as if made less, the flank will not occupy the whole of the prolongation of the ditch it flanks, and the greater part of its length will be in the prolongation of the superior slope of the parapet of the line flanked.*

This would be the case if in Fig. 188 the auxiliary flank were only as long as *a d*.

The auxiliary flank *a b*, Fig. 188, should always be protected from enfilade fire by a short length of parapet *f g*, which may be traced in the line *c d* produced, if the redan were flanked by works in rear; if otherwise, *f g* may be parallel to the face *c d*.

224. A Double Redan (Fig. 190) consists of two redans joined together, their outer faces being longer than the two others, which should form a flanking angle of 95° or 100°. This work, in its nature, defects, &c., is similar to the redan, except that it is stronger, owing to the cross fire on the salients. Fig. 190 is evidently a stronger work than a redan of the same length of parapet.

A Triple Redan is one having three salients and two re-entering angles.

A Blunted Redan (Fig. 191) is an open work with three faces, affording fire to the front and to each flank. It approximates in shape to the half of a regular hexagon.

225. A Lunette (Figs. 192—194) is a work with two of its faces forming a salient angle, and two other faces, called "flanks," parallel, or nearly so, to the capital: as a general rule, however, the flanks are traced perpendicularly to the direction in which they are required to fire.

The angles formed by the faces and flanks are the *Shoulder angles*.

Faces of from 40 to 50 yards, and flanks of from 20 to 30 yards in length, are ordinary dimensions for lunettes.

A Blunted Lunette, Fig. 193, is similar to the lunette as in Fig. 192, with the salient cut off by a parapet firing on the capital of the work.

The defects above quoted, as belonging to redans, apply equally to lunettes, as also the methods of remedying them, &c., and the positions suitable for the work.

226. Open works generally are preferable to closed works in positions where there is a defence for their gorges, as in advanced works, for instance; because, should the enemy gain possession of them, he would still be exposed to the fire of the works in rear, or to the attack of troops sent against him.

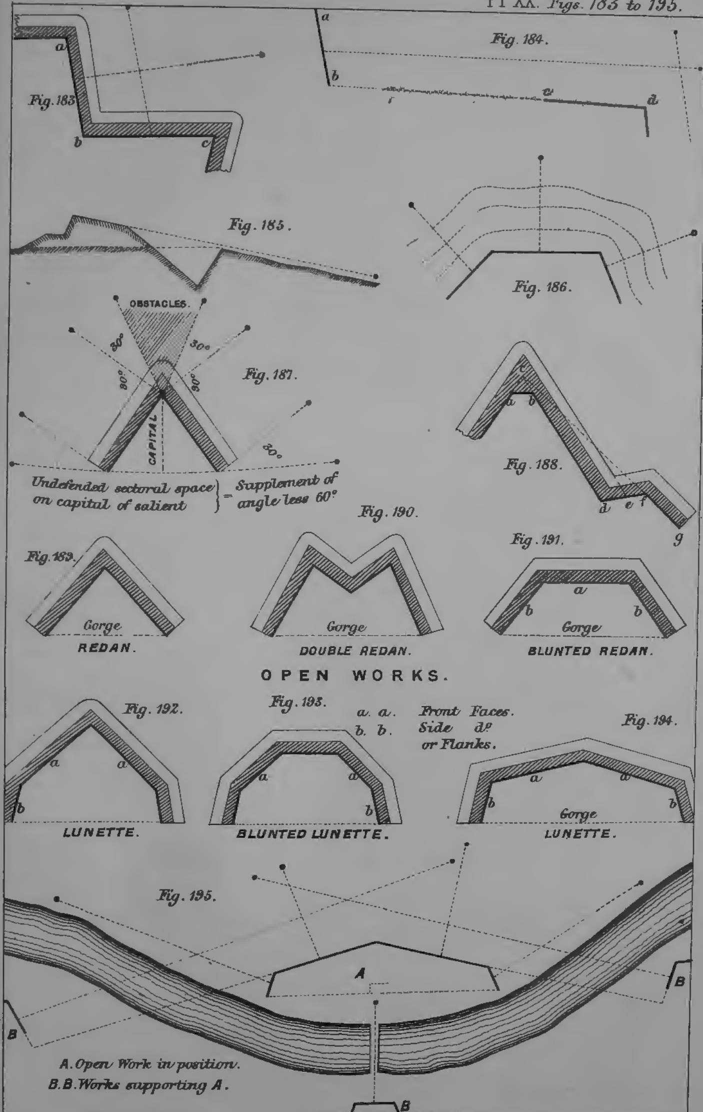
In advanced situations, as a guard against surprise, it is generally desirable to close the gorges of works either by a thin earthen parapet, stockade work, or a line of obstacles, in which case, as already stated, the works are now called *half-closed* works. This arrangement would afford no cover from *artillery* fire to an enemy who had succeeded in effecting their capture.

A redan or lunette by itself has many defects, as has been pointed out; but when judiciously selected and supported it may become a very formidable work. This will be evident from an inspection of Fig. 195, where the Lunette A is intended to protect the head of the bridge from attack.

In this position the gorge is naturally closed by the river; the works B B flank, *from secure positions*, the faces of the lunette, and bring a cross-fire on its capital. The ditches may also be filled with water, if the site allow, and are exposed to flanking fire from B; and should an enemy get possession of the

* This applies only to earthen parapets. A flanking stockade or wall giving only a single loophole may frequently be sufficient for the object, as, for instance, to flank the wall of a house from its porch.

Pl XX. *Figs. 183 to 195.*



work, the interior, as well as the passage over the bridge, is exposed to the fire of the work B in rear of the bridge. Fig. 195 illustrates also a principle in fortification—viz., to arrange works so that an enemy, when attacking one work, must be exposed to the fire of as many other works as possible.

Redoubts.

227. When a closed work has no flank defence for its ditches from its parapets, it is called a *Redoubt;* and when it has a parapet flank defence for its ditches, and therefore re-entering (flanking) angles, it is called a *Fort.*

Closed works of every kind have the inconvenience of having some of their parapets exposed to be enfiladed or taken in reverse, for, on whatever side an enemy opens fire, the projectiles that clear the parapets of the faces opposed to him take in reverse those of the further sides, or enfilade the lateral faces of the work; and from the fact that the work is a closed one, an attack from any side, or all sides at once, is possible, and therefore every part may be liable to be enfiladed, or to be taken in reverse.

It is not here implied that every part of a closed work is equally liable to these disadvantages; for as one portion of a work will face the front of a position, the front faces will not generally be liable to be taken in reverse until after an enemy shall have penetrated to the rear.

Another defect inherent in closed works is, that the garrison when attacked are confined in a comparatively small space, and suffer, in proportion, from the effects of the enemy's fire, which may be concentrated on the work from various points, previously to its being assaulted. To illustrate this, compare the situation of the garrison of a square redoubt having 100 yards of parapet with the defenders of a straight line of parapet 100 yards in length, exposed only to fire from the front, and manned by the same number of men as the redoubt. The disadvantages under which the former labour will be evident; for with the straight line of work every projectile that clears the parapet passes to the rear without further damage, but with the redoubt the projectiles are arrested by the other parapets, and the effects of the enemy's fire, particularly that of shells, increased.

These disadvantages of closed works necessitate the construction of *traverses* (see Chapter V.) of various kinds, inside the work; these traverses, however, occupy much of the interior space, which, in consequence, becomes cramped, and the defence suffers in proportion.

These disadvantages are more fully felt in small works than in large ones, for in small works an enemy's fire becomes more concentrated, the defenders are confined in an area smaller in proportion to their numbers, and there is less room to construct proper traverses than in large works.

In comparing the space inside a small work with that inside a larger one of similar shape (say two squares), it will be observed that, while the garrison of the two works will be in direct proportion to the length of the sides of works (or length of parapet), the interior space will be (nearly) in proportion to the *squares* of the sides.

These defects are so well known, that it is almost a maxim in Fortification that "Small works are bad works," whether a redoubt, a fort, or a fortress, is referred to; but Field Works must be used of a size suited to the garrisons that can be spared to defend them, and when small works are necessary they must be made the most of.*

* To give an idea of the garrisons ordinarily allotted to Field Works, it may be here mentioned, that of the works forming the celebrated Lines of Torres Vedras—

6	had garrisons	under 100 men	Exclusive of artillery.
39	,,	of from 100 to 200 men	
47	,,	,, 200 to 300 ,,	
33	,,	,, 300 to 400 ,,	
3	,,	,, 400 to 500 ,,	

And 10 works had a garrison of more than 500 men.

228. It is, however, desirable to fix the minimum size that a redoubt should have, and as a general rule it may be laid down that a redoubt should not, under ordinary circumstances, have less than 100 yards of parapet.

On the other hand, it is undesirable to fix a maximum size that a redoubt should have—*i.e.*, when the unflanked trace of a redoubt should give way to the flanked trace of a fort; in fact, for most cases of separate field-works the simple outline of a redoubt which gives a maximum of frontal fire is preferable to the complicated trace of a fort, which sacrifices frontal to flank fire, and cramps the interior space.

Experience of actual campaigns shows that the garrison of a field-work is seldom more than half a battalion, and that the length of parapet (firing line) for the same does not much exceed 250 yards; and it may safely be asserted that a redoubt of 250 or 300 yards of parapet will in most situations be preferable to a field fort having the *same length of parapet* and requiring an equal garrison.

Size and Shape of Works and Garrison.

229. The *size of a work* depends generally on the number of troops that can be spared to garrison it. Sometimes, however, the shape of the ground occupied by it fixes a minimum size, and consequently a minimum garrison to the work.

The *shape of a redoubt or other field-work* is usually fixed by the directions in which its principal faces are required to fire: the front faces being traced for fire on the *front of the position*, the side faces for defending intervals and the salients of collateral works, while the rear faces may be traced so as to enclose sufficient space, to be free from enfilade, &c.

The *garrison of a redoubt or other field-work* should always consist of some tactical unit or units, varying from a company to a battalion.

Villages and other improvised supporting points may require from one to three battalions, according to size.

230. The *distribution of men* may ordinarily be reckoned as follows:—

One man to every yard of crest line on principal faces, as a shooting line.

Half as many (*i.e.*, 1 man to every 2 yards) at foot of banquettes or in rear trench as supports, and to replace casualties.

In addition, $\frac{1}{4}$th to $\frac{1}{8}$th of the whole garrison as a reserve in the interior to charge the enemy if he penetrates. The reserve should itself be a tactical unit: a company or a half-company for instance.

In making rough calculations, 2 men per yard may be allowed all round, including reserves, for closed works; and $1\frac{1}{2}$ men per yard for half-closed works. In very isolated situations the garrison may be 3 men per yard, including reserves.

231. It is not, as a rule, advisable to place guns in works when good positions can be found outside, as their mobility is lost, and they may be silenced by the heavy fire which generally precedes the assault of the works. It is, however, usual, in the larger redoubts, to adapt certain portions of the parapet (chiefly at the salients where the field of fire is the greatest) for the use of guns.

The number of guns would not ordinarily exceed 12, and never less than 2. Machine guns are specially useful for firing along weakly defended capitals, and for flanking fire.

No allowance need be made for guns mounted *en barbette*, as this does not prevent the infantry using the parapet when the guns are withdrawn or disabled; but when in embrasure, a deduction of 5 yards per gun should be made for the space available for infantry.

Deductions for traverses should be made according to their size, and the length of crest occupied by them.

232. The above conditions determine the size of works, *i.e.*, the total length of crest, or firing, line; and this must be distributed amongst the faces according to the importance of the fire they have to furnish. Flanks for infantry fire should never be less than 12 yards: if for artillery fire, not less than 25 yards

Example.

Find length of crest line of a closed field redoubt to be held by a force of 4 companies of infantry (100 rank and file each) and 3 guns; 1 company in reserve, guns *en barbette.*

$$\left.\begin{array}{l}\text{Shooting line and}\\ \quad\text{supports together}\end{array}\right\} = \tfrac{3}{4} \times 400 = 300 \text{ men.}$$

$$\text{Shooting line} \quad = \tfrac{2}{3} \times 300 = 200 \text{ men.}$$

As the guns are *en barbette*, no addition need be made for them; and the number of the shooting line will be *the length in yards* of the crest line, viz., 200.

This length of 200 yards would be distributed amongst the faces of the work, according to circumstances.

A good ordinary distribution would be 70 yards for front faces, 50 yards for side faces, and 80 yards for rear faces.

233. The weak parts of all redoubts are (1) want of direct fire on the capitals of the salients, if the angles be small; (2) no flank defence; and (3) the ditches are *dead*, being unseen from the work.

The want of fire in the direction of the capitals may be remedied, as in open works, by using a machine gun at the salient, or by filling up an angle so as to form a short face or a curve, having room for a few files (6 or 7) to fire on the capital, at the same time obstructing the approach of the enemy in that direction by all available obstacles.

Guns are also frequently placed *en barbette* (see Chapter V.) at the salients; but artillery in a field-work are usually posted for offensive purposes, such as to bring a fire on ground over which an enemy must advance to an assault, or to enfilade a road or bridge, or to flank some other work; but for the close defence of a work, it is considered that the parapet required for a gun would be better occupied by infantry, the gun being more usefully employed outside.

The defect of the ditches being unseen from the parapets is peculiar to most field-works (except very large and exceptional ones having their own flank defence), and, as has been before mentioned, one great object of defence is to prevent an enemy, as long as possible, from getting into the ditches, by detaining him under a close fire, by means of obstacles arranged for that purpose.

But when time and circumstances admit, a flank defence for the ditches of redoubts (and any other kind of work requiring it) may be obtained by forming in them "*Caponiers,*" either at the angles or in the middle of the faces, or by loopholed galleries termed "*Counterscarp Galleries,*" behind the counterscarp at the angles of the work.

234. A Caponier (Figs. 199, 200) for the ditch of a field-work is a covered building, the walls of which are made of stockade-work and are loopholed. It is roofed over with beams, planks, or fascines, with earth on the top, in order to secure the men within from the effects of shells, or a plunging fire from the counterscarp. The roof should project 2 or 3 feet to keep out the weather, and as additional security against curved fire. It ought to be flanked by musketry, and its salient should be brought to a point or rounded to prevent an enemy closing on it and getting under cover. A gallery of communication is constructed, leading to the interior of the work.

The caponier should extend across the original width of the ditch, and the counterscarp should be enlarged round its salient, to prevent an enemy using it as a bridge—a clear breadth of 8′ and a height of 6′ or 7′ are usually given. The floor-line of the caponier may be sunk 3 or 4 feet below the bottom of the ditch, as the roof thereby becomes lowered a similar amount, and the work better covered from artillery fire; but when this is the case, precautions are necessary to keep the floor of the caponier drained.

The difficulty of draining the work, if its floor be sunk below the bottom of the ditch, may frequently render it imperative to keep its floor on the level of the bottom of the ditch.

235. In general, the best position for a caponier is at an angle, as in that position one work can flank two lines of ditch; it has, however, in that position the inconvenience of having its walls, when parallel to each other, oblique to the lines of fire which correspond to the direction of the ditches; this is, of course, more felt with small salients than with large ones.

Fig. 199 shows a shape for a caponier at a salient angle; each side is made perpendicular to the ditch it flanks, and the head of the work forms a re-entering angle, thereby allowing it to be flanked.

Works formed with stockade-work can be destroyed from a distance if exposed to artillery fire; therefore, whenever a caponier is used, it must be carefully protected from the effects of artillery. This will be best effected, in general, by placing it at the angles *nearest the enemy's position*, as then the counterscarp and glacis in front cover it from fire, enfilading either of the ditches flanked by it.

The sketch (Fig. 200) shows how redoubts can be flanked by caponiers, all of which are placed so as to be safe from artillery fire enfilading the ditches, from the front of the position, which is supposed in the figure to be the top of the page. Three caponiers are required to flank four lines of ditches.

236. A Counterscarp Gallery (Fig. 201) is somewhat similar to a caponier as its front wall is constructed of stockade-work, and it is roofed similarly to a caponier. It is constructed necessarily at an angle; and when used to flank two ditches, it has in itself reciprocal defence. A door of communication leads to the ditch, from which a gallery into the work is necessary.

The objection urged against Counterscarp Galleries and also Caponiers is the isolation of the defenders, which prevents their being under the immediate supervision of the officer commanding in the work. They have, however, the great advantage of being able to be placed in positions of perfect security from artillery fire.

As a means of defence neither *field* Caponiers nor Counterscarp Galleries are considered to repay the labour of construction, except in large deliberately constructed works, with deep ditches.

It may be presumed, whenever auxiliary flank defence, whether by Caponiers or by Counterscarp Galleries, can be provided for the ditches of works, that the ditches themselves will be palisaded or fraised, and every possible contrivance resorted to, to render the passage of the ditch, under the flanking fire, a work of difficulty.

237. The garrison of a closed work communicate with the exterior by means of a passage from 6 to 12 feet wide, formed in the parapet on the side least exposed to fire. The passage should be closed by a musket-proof loopholed gate; and when artillery can be brought to bear on it, a traverse to cover the entrance should be thrown up inside the work. Across the ditch a bridge, having the same clear breadth as the passage, is formed of planks resting on beams, which latter are termed *baulks*.

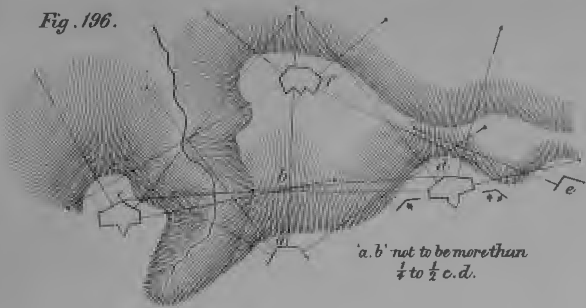
For details of the construction of the Passage, Gateway, Traverse, and Bridge, see Chapter V., Details.

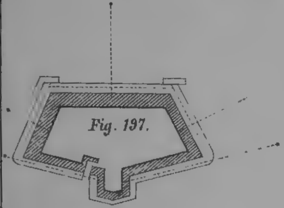
238. A Blockhouse, Plate XXII., is a covered loopholed building, usually rectangular in shape, which acts as a defensible barrack, or guard-house. The walls are usually of stockade-work, and the roof formed of beams or iron rails and planks or fascines, covered with 3 or 4 feet of earth. The roof should project 2 or 3 feet, so as to keep out weather, and afford protection from curved fire.

They may be used as separate works in mountainous countries, if artillery cannot be brought against them, in positions where ordinary field-works would be seen into from the neighbouring heights.

REDOUBTS &c.

Fig. 196.





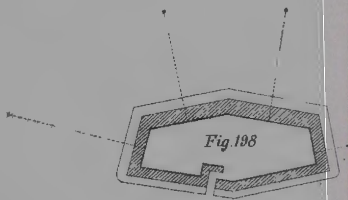


Fig. 200.

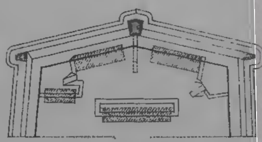
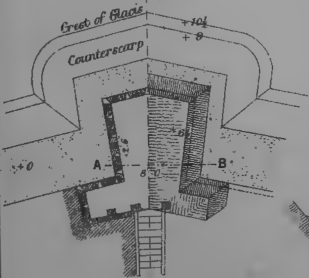


Fig. 199.
Centre Caponier.



Section A.B.

Counterscarp Gallery.

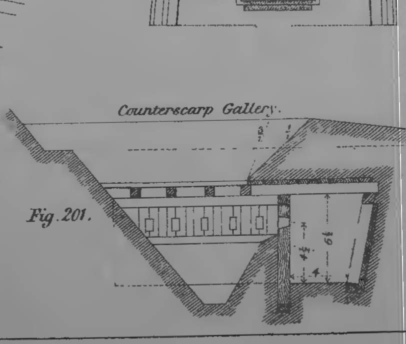
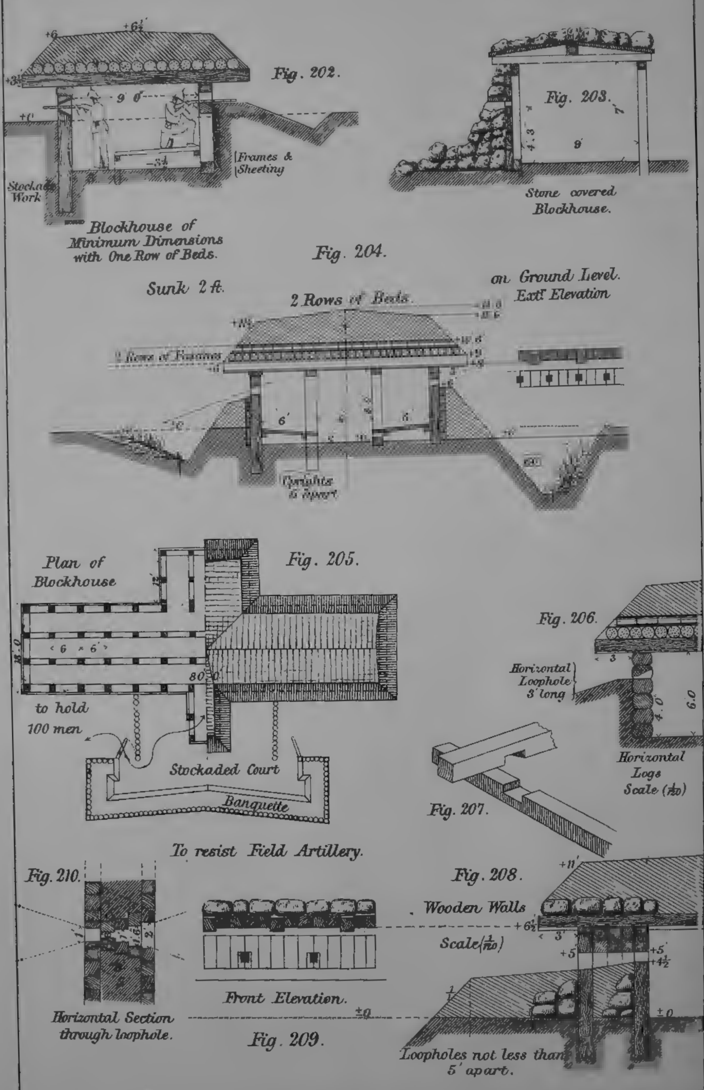


Fig. 201.

BLOCKHOUSES.



They are most useful in wars against savage tribes, for they combine the properties of a distinct work and the barracks of the garrison. They can also be held by a very few men.

Their use also comes into play in civilised warfare as keeps or reduits to field-works inside which they are placed, and where they receive protection from artillery fire by means of the parapets of the main work.

239. The breadth of a blockhouse will depend on whether one or two rows of beds are used.

The minimum breadth is shown in Fig. 202, where 6′ is allowed for the bed and 3′ for passage, making 9′ in all.

If two rows of beds are used, as in Figs. 204, 205, the passage ought to be broader, say 6 feet, and the minimum breadth will be 18 feet, as shown. The beds, which are like ordinary guard-beds, act as banquettes to the loopholes. The interior height may vary according to requirements from a minimum of 6 feet, as in Figs. 202—206, to 8 or 9 feet, as in Fig. 204.

The length of the building depends on the number of men it is required to hold, allowing 2 feet lineal on the guard-beds for each man.

The usual precautions should be taken, by means of ditches outside the walls, obstacles, &c., to prevent an enemy closing on the building, as shown in the illustrations.

When used as keeps to field-works they should be kept as low as possible, by sinking their floors below the ground, and by using a minimum height inside, so as to protect them from artillery projectiles; both these conditions are complied with in Fig. 202.

240. When ordinary stockade work is used for the walls the timbers should be squared, so as to be in contact for 10 or 12 inches. The walls may also be made of horizontal timbers as in Fig. 206; the timber should be long enough to project at the corners, and should be halved into one another as shown in Fig. 207. In those cases the loopholes may be horizontal and cut out of a single timber Fig. 206. The walls may also be made of timber frames and sheeting (planks) as in Fig. 202 on the right; or in Fig. 203 on the left.

In mountainous and rocky districts, when exposed to infantry fire only, excellent defensible guardhouses or blockhouses can be made out of light frames and sheeting covered by stones built up dry on the outside and on the roof. (Fig. 203.)

241. Large and important blockhouses such as are illustrated in Figs. 204, 205 may be built in the form of a cross, which will afford flank defence. Fig. 205 is the plan of a blockhouse to hold 100 men or a full company. The entrance, made on the most convenient side, is protected by a stockaded defensible enclosure.

When circumstances permit and no artillery fire is to be feared, such as in warfare against savage tribes, blockhouses may be made in two storeys, the upper of which is placed diagonally over the lower one. The upper storey affords to the garrison a better view and command over the surrounding ground, while it permits fire to be distributed all round. The floor of the upper storey would be loopholed, so as to fire on to the lower floor, and also from the projecting angles to the foot of the walls outside.

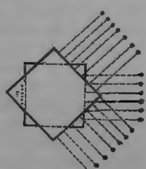


Fig. 211.

Means of retreat to the upper floor should be provided.

242. *Blockhouses to resist light artillery* require to have thicker and stronger walls and also roofs than those before described. Their construction is complicated and beyond the limits of this work to describe fully.

Railway iron would be freely used to strengthen the walls and roof.

An example of a timber building as the most simple illustration is given in Figs. 208, 209. Here the walls are doubled and are 3′ apart, the space between being filled with earth and large blocks of stone. Outside the walls is an earth parapet, as high as the loopholes, large blocks of stone being embedded in the parapet in contact with the walls. The roof covering is also strengthened by blocks of stone over the cross timbers and near the front of the building over which the roof projects.

The details of the loopholes, shown in Figs. 208 and 210, evidently involve much work, and such a building as is here referred to would seldom require to be made, but when undertaken, no pains would be spared to enable it to be effective.

Forts. (Plate XXIII.)

243. *Forts* have been referred to in Art. 227 as "closed works having flank defence from their own parapets;" they are larger works than redoubts, *i.e.*, they have a greater length of parapet and require a greater garrison, because parapet flank defence necessitates re-entering angles, involving increased length of parapet; and re-entering angles cause a loss of interior space, which cannot be spared in works of the magnitude of ordinary field redoubts.

The advantages of the fort trace do not fully exist unless the re-entering angles are of size proper for "flanking angles," and to make them of such a size the salient angles must be reduced in size accordingly, and many drawbacks attend the use of small salients, as stated in Art. 222 (7).

In general terms it may be stated that Redoubts depend upon their own frontal fire for defence, leaving the ditch unflanked, but obstructed as much as possible with obstacles; while the ground in front of their salients is defended by adjacent works or by troops in position outside; whereas Forts have their own flank defence, which bears not only on the ditches, but should cross-fire on the capitals of the salients, each of which would thus be protected by a double fire.

Redoubts are especially suitable as mutually supporting works, where the weak points of each work are strengthened by the fire of other works: in cases, however, where an important work, in an isolated situation where it could not receive efficient support from other works has to be made, (such as Fort Sultan in the Lines of Gallipoli in 1854) and held by a large garrison of one or two battalions, a Fort might be constructed.

It will therefore be evident that a Field Fort is altogether an exceptional work; and likely, moreover, to be more exceptional in the future than it has been, owing to the great range and rapidity of fire of modern arms having much increased the value of frontal fire.

It may, however, happen that the shape of the ground on one or more sides of a work may render it necessary to have re-entering angles at those portions, and therefore more or less parapet flank defence; in which cases the outline of the work would be a partial combination of the Redoubt and the Fort.

A comparison of the two traces may be made from Fig. 212. In this figure the salients *a*, *b*, *c*, &c., are fixed by the shape of the ground, and a fort is represented in outline by the continuous lines with the re-entering angles at *g*, *h*, &c., while the polygon shown by the dotted lines *a b*, *b c*, *c d*, &c., would give the outline of a redoubt for the same site. With the Fort trace there is much exposure to enfilade fire, a series of small salients, and a loss of interior space as compared with that of the Redoubt: all these defects being incurred in order to obtain the flanking re-entering angles.

Two kinds of Forts have been constructed, viz., *Star Forts* and *Bastioned Forts*, each with modifications. These will now be described.

244. Star Forts are works composed of faces forming alternately salient and re-entering angles, the salient angles being 60°; and are so named from their form being like the usual representation of a star.

When regular in shape, they may be traced in a variety of manners; the following seems as good as any other (Fig. 211).

Trace a regular polygon, of the same number of sides as the work is to have salients, each side of the polygon being of the length of the intended faces of the fort; and on each side of this polygon, erect an equilateral triangle to get the faces of the work. Thus, if a six-pointed star fort were required to be traced, so as to have 360 yards of parapet, a hexagon would be first traced, each side being $\frac{360}{6 \times 2} = 30$ yards in length, and on each of these sides of 30 yards an equilateral triangle would be raised to obtain the faces of the work.

The salients of star forts are usually made 60°, as by so doing the re-entering angles become better flanking angles.

To trace a star fort when the nature of the ground, &c., requires an irregular work, the following method is the most convenient. First select the salients *a*, *b*, *c*, *d*, *e*, Fig. 212, as their position is the most important, and is usually to a great degree fixed by the nature of the ground; bisect the angles formed by the exterior sides *a b*, *b c*, *c d*, *d e*, *e a*, which join these points, to get the capitals of the salient angles; and from each of the points, *a*, *b*, *c*, *d*, *e*, draw lines making angles of 30° with these capitals to get the faces, which are then produced until they meet.

This method, which is easy of execution on the ground, will give re-entering angles of a size as nearly approaching good flanking angles, as can be done without making the salients too small.

Star forts, consisting of re-entering as well as salient angles, were intended to obviate, in some degree, the main defect of redoubts; they, however, do not even partially obviate it unless (as in Fig. 211) constructed on polygons not inferior to a hexagon; as even on a hexagon, the flanking being 120°, the fire from the faces, though it crosses the capitals, affords but little defence to the ditch; on polygons inferior to a hexagon, they afford a fire which crosses at so great a distance from the salient as not in an effective manner to flank it.

A great portion of the ditches of star forts, *whatever may be the number of salients*, is *dead* at each re-entering angle. The actual amount of dead space at a re-entering angle will depend on the relief of the work and on the depression of the superior slope: thus, if Fig. 214 represents a section through the face of a star fort and the ditch opposite to it, the relief being 17′, it will be seen that it will be $6 \times (17 - 3) = 84$ feet before the fire from the parapet, with a depression of 1 in 6, can defend the ditch, which it is usual to consider properly effected when fire can be directed within 3′ of the bottom.

With a superior slope of $\frac{1}{4}$ this distance will be $4 \times (17 - 3) = 56$ feet. Thus, whatever may be the size of the re-entering angles, there will be a dead space in the ditch, varying, as above shown, from about 20 to 30 yards in a work having a relief of 17 feet. Hence if it be considered necessary to have some portion of the ditch near the salients flanked, no side or face should be made of a less length than 25 to 35 yards, according to the depression of the superior slope.

A steeper slope than usual may be given to the superior slope of a star fort, at those parts of the faces which occupy the prolongation of the ditches, as by so doing the dead space in the ditches will be reduced, and the defect of weakening the parapets at the parts named will not be of much importance, as re-entering angles are less exposed to artillery fire than the other parts of works.

Star forts, as a class, have many defects, which may be summed up as follows, it being remembered that most of these defects are less felt in large than in small works.

Owing to the numerous angles, and the great thickness of the parapet and slopes at a salient of 60° (twice that on a perpendicular to the face), the construction of star forts is attended with trouble, particularly if the ground be uneven. The small salients are each a favourable point of attack, and are not well flanked in polygons inferior to an octagon, and in all cases may be enfiladed; the ditches are dead for many yards on each side of the re-entering angles; the length of parapet to be manned is great, when compared to the interior space, and is exposed to reverse and enfilade fire in all directions, and there is seldom room for sufficient traverses to lessen the effects of such fires.

245. Fig. 215 represents the outline of one front of a work termed a Double Star Fort, which has many comparative advantages; these, however, are chiefly owing to its large size. In the example here given, the small blunted redan, A, affords a powerful flank defence to the main salients, without being itself liable to attack, owing to its strong position, *as it is situated in a re-entering position.* The interior space is ample, and the work generally is not more exposed to enfilade fire, while the flanking parapets are much less exposed to reverse fire, than is the case in bastioned forts. It has the further advantage over a bastioned fort (of equal garrison for purposes of comparison) of having a much shorter length of line of defence, which implies a more effective flanking fire, and since the flanking parapets (the faces of redan A) face outwards from one another, there is not the possibility of one flank firing into the other, as is the case with the flanks (E G and F H, Fig. 216) of a bastioned fort. Each of the sides of the polygon in Fig. 215 is 120 yards in length (the trace is not suitable for shorter fronts), and the work has altogether about 700 yards of parapet; it would, therefore, require *at least* 1,000 men for its defence.

246. Bastioned Forts (Figs. 216 and 220) are sometimes considered the most perfect of closed Field Works, as they possess the advantages of mutual defence between their several parts, their ditches are (when properly constructed) seen throughout from the parapets, and every part of the exterior ground is exposed to the cross-fire of at least two lines of parapet.

While possessing these advantages in their trace, bastioned forts can be rarely used on account of the large garrisons they require, the smallest bastioned fort having in round numbers 600 yards of parapet; they are therefore only applicable to very important positions, and then all available means and labour should be expended on them, in order to make them as formidable as possible; and all the accessories of defence, such as abatis, trous-de-loup, palisades, fraises, &c., already described, should be resorted to, in the positions most suitable for them.

The following is the method of tracing these works, when regular, a square being here taken (Fig. 216) as an example.

The points A, B, &c., at the angles of the square, are first fixed. The sides

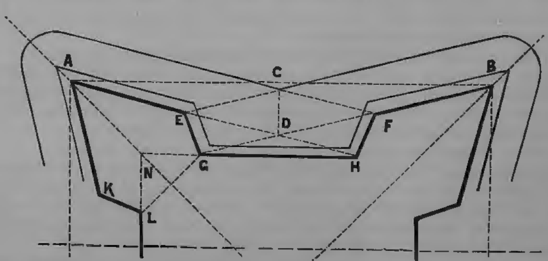


Fig. 216.

A B, &c., of the square are termed *Exterior sides*, and on each exterior side the following construction is performed :—

Bisect A B in C; through C draw *the Perpendicular* C D, perpendicular to, and ⅛th of, A B; join A D and B D, and produce them to obtain the *Lines of defence*, A H and B G: on these lines of defence set off A E and B F, each equal to $\frac{2}{7}$ths (sometimes ⅓rd) of A B, to obtain the *Faces of the bastions;* through the points E and F draw the *Flanks*, E G and F H, at angles of 95° with their respective lines of defence, B G and A H; join the points G and H, to obtain the *Curtain*, G H, which completes the trace of the parapet of one side of the work or, as it is termed, "*a bastioned front of fortification*," which thus consists of *two faces, two flanks*, and the *intermediate curtain*.

The names of the different parts, not mentioned above, are the following :— L K A E G is *a Bastion*, similar in shape to a lunette ; L G is the *Gorge* of the bastion ; G N or L N the *demi-gorges ;* A N *the Capital ;* K A E the *flanked angle ;* A E G or B F H the *shoulder angles ;* E G B and F H A *angles of defence* or *flanking angles ;* E G H and F H G the *curtain angles* or *angles of the flank ;* and A B D and B A D the *diminished angles.*

It will be evident, on considering the preceding construction, that if the perpendicular C D were increased in length, it would have the effect of increasing the length of the flanks E G and F H, and at the same time it would decrease the size of the flanked angles K A E, &c.

The reason why the perpendicular is only made $\frac{1}{8}$th of the exterior side, in a square fort, is that, if it were larger, the flanked angles would become less than 60°.

When a fort is constructed on a regular pentagon, where the angles of a polygon are 108°, the perpendicular is made $\frac{1}{7}$th of the exterior side, as the flanked angle will then be larger than 60°, while the length of the flank is increased; and when a work is constructed on a hexagon, where the angles of the polygon are 120°, a perpendicular as large as $\frac{1}{6}$th of the exterior side can be made use of, and a still larger flank thereby obtained, without having too small a flanked angle.

The perpendiculars are not made more than $\frac{1}{6}$th of their respective exterior sides, whatever may be the size of the angles of the polygon, as with that length a flank long enough is obtained.

The exterior sides of a bastioned fort may be any length most convenient, from 120 yards as a minimum upwards.

The minimum length is here fixed at 120 yards, because that length, with a perpendicular of $\frac{1}{8}$th, gives a flank about 12 yards in length, which is the smallest size a flank should have to be at all formidable ; and if the exterior side were made less than 120 yards, the distance G D or H D, in Fig. 201, would become too short to allow the point D to be defended from the flanks, with the ordinary relief of about 18 or 20 feet.

An exterior side of more than 240 yards would seldom be required in a field work ; this would give a line of defence 170 yards in length.

247. The ditch of a bastioned front requires a peculiar construction, in order to derive the full benefit of the flanking defence obtained by the bastion trace.

If the counterscarp of the front were made parallel to the escarp, as is the method with ordinary works, the counterscarp of each flank would prevent the fire from the opposite flank defending the ditch of the face nearly throughout its entire length ; the ditch of each flank would also be hidden from the fire of the opposite flank.

By cutting ramps (Fig. 218) in prolongation of the ditches of the faces, those ditches become exposed to the fire of a *portion* of the flank, and a great improvement is effected with the expenditure of only a little labour ; but still, merely that portion of the flank which occupies the prolongation of this ramp is available for the defence of the ditch. In order, however, to allow the whole fire from the flank to defend the ditch, the construction shown in Fig. 217 must be resorted to. Here the counterscarp at one shoulder angle is directed on to the shoulder angle of the opposite bastion, and the whole of the ground between the original counterscarps of the two flanks is ramped, as shown in the sketch, Fig. 219 ; or it may be removed entirely, if considered necessary. This construction involves a great expenditure of labour, which, so far as is known, has never been incurred in any bastioned front thrown up in the field. But there would be no difficulty in forming the ramps as in Fig. 218.

248. When the shape of a bastioned fort is necessarily irregular, on account of irregularity of the ground or other causes, the salients A, B, &c. (Fig. 220), would be first selected: these points may be at any distances apart most convenient, from 120 yards upwards, provided that in no case is the angle formed by two adjacent exterior sides less than 90°.

This will usually lead not only to having exterior sides of different lengths, but also to the angles of the polygon being of different sizes, and the construction of the fort becomes more intricate than with regular polygons.

In Fig. 220 an irregular pentagonal bastioned fort is drawn in outline. The angle of the polygon at A is 103°; that at B, 127°. In constructing the work, the two faces of the bastion whose salient is at A would be determined by using perpendiculars $\frac{1}{8}$th of their respective exterior sides,* because, if longer perpendiculars were used, the flanked angle at A would become too small; but to

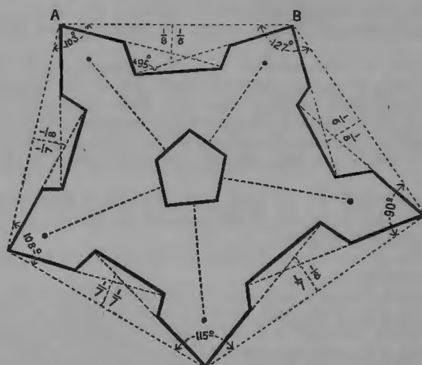


FIG. 220.

trace the two faces of the bastion whose salient is at B, perpendiculars $\frac{1}{6}$th of their respective exterior sides can be used, and large flanks thereby obtained. Hence two perpendiculars are required to each front, whenever the angles of the polygon at either end differ from one another as much as do the angles of a regular square (90°), pentagon (108°), or hexagon (120°).

Fig. 220 shows the advantage of having large angles to polygons, and therefore (indirectly) of large works in general, for the flanked angle at B is larger than at A; and in addition to this, its flanks are longer than those defending the faces of the angle at A.

249. DEMI-BASTIONED FORTS (Fig. 221) are traced similarly to those with bastions; but only one flank is used to each front, its line of defence being an unbroken line of parapet.

This trace is defective, inasmuch as each angle of defence is dead, and the face of each demi-bastion receives only very oblique defence from the long face of the same front. Against these defects the slight increase of interior space gained, compared to the bastioned trace, is no advantage, as in these large works the interior space is ample for every requirement; therefore complete works on this trace are not usually recommended.

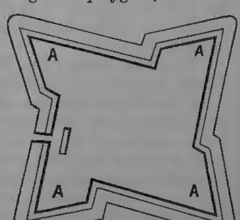
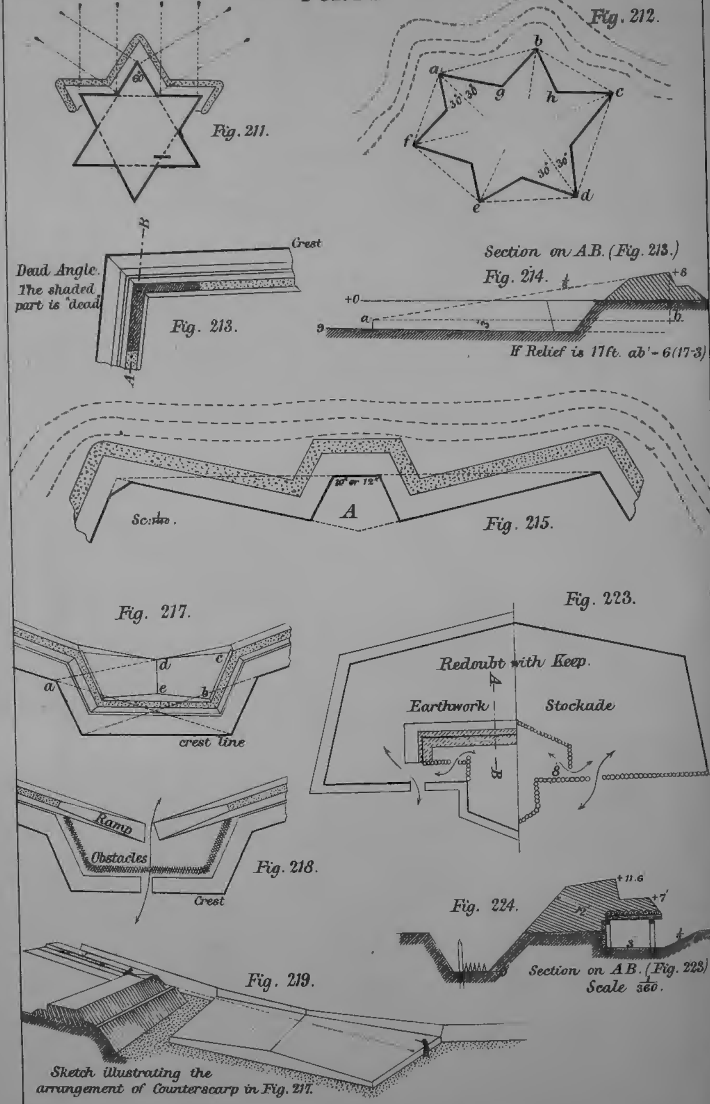


FIG. 221.

* A perpendicular of $\frac{1}{8}$th the exterior side must be used for any exterior angle less than 108°; $\frac{1}{7}$th when the angle is between 108° nd 120°; and $\frac{1}{6}$th when 120° or larger.

FORTS.


60°
Fig. 211.
Fig. 212.
a
b
c
d
e
f
g
h
30° 30°
Grest
Dead Angle.
The shaded part is "dead"
Fig. 213.
A
B
Section on AB. (Fig. 213.)
Fig. 214.
+0
+8
a
b.
If Relief is 17ft. ab' = 6(17-3)
Sc: 1/400.
10' or 12'
A
Fig. 215.
Fig. 217.
a
b
c
d
e
crest line
Fig. 223.
Redoubt with Keep.
Earthwork
Stockade
A
B
Ramp
Obstacles
Fig. 218.
Crest
Fig. 224.
+11.6
+7'
Section on AB. (Fig. 223)
Scale 1/360.
Fig. 219.
Sketch illustrating the arrangement of Counterscarp in Fig. 217.

There are many positions, however, where the trace can be partially resorted to. In the case of the work shown in Fig. 222, as covering the bridge D from attack, the demi-bastioned trace is particularly suitable; the flanks being traced so

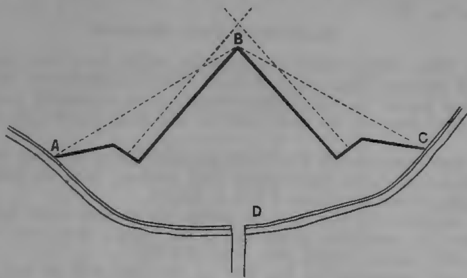


Fig. 222.

as to flank the angle B, and cross their fire on the ground in its front, where it is most required. The angles A and C are evidently safe from attack.

250. A Reduit or Keep is a work constructed within another, or it is some portion of a work separated from the rest, with the object of prolonging the defence after the main work shall have been forced.

A room may be used as the reduit of a house; a redoubt, of a fort; and even in a redoubt, a reduit may be made, in the shape of a small blockhouse. When a village is entrenched, some large building, such as a church or jail, is usually selected to act as a reduit.

The trace of a reduit constructed inside a work depends on that of the main work; if a redoubt, it should be traced so as to be able to fire into those parts of the main work where an enemy is most likely to penetrate. These are generally the salients, to each of which there should be one face of the reduit opposed, as in Fig. 220, which shows a fort of an irregular trace, provided with a reduit in the shape of a redoubt, each face of which fires towards a salient of the fort.

When a redoubt is used as a reduit, it should have a command of 4 or 5 feet over every part of the main work, in order that the enemy, when he has gained the parapet of the main work, may not be able to fire into the reduit. This will lead to the absolute command of the reduit being very great, at least 13′ or 14′; and, in order to save interior space in the fort, the exterior slopes of the reduit may be revetted. Frequently the inner work may be constructed without a ditch, the earth to form it being procured by sinking the terreplein of the main work, or from its ditch. Obstacles should in this case be arranged along the face and foot of the exterior slope of the reduit.

Blockhouses, or other covered works, are suitable for reduits to works, as it is not necessary to give them the excessive command required for the earthen works (when so used) mentioned in the last paragraph; indeed, their floors should be sunk sufficiently to hide them from external view—a great advantage, considering the accuracy of fire of the artillery of the present day.

Figs. 223, 224 show a large redoubt provided with a keep at its gorge. The right half of the plan shows a stockaded gorge with keep: the left half shows the keep as being composed of an earthwork with good command ($11\frac{1}{2}$ feet), seeing into, and commanding with its fire, the interior of the redoubt: it is also provided with *field casemates* under its parapet, for the shelter of its garrison. It is connected with the gorge parapets by a stockade. This would form a good reduit.

The garrison of a reduit should be a distinct unit, usually one company or more.

The entrance to the main work must not pass through the reduit: this is shown in Fig. 223.

Examples of Field Redoubts.

251. Plate XXIV. gives two examples, which have been prepared at the School of Military Engineering, of Field Redoubts suitable for one of a line of "tactical pivots," or "supporting points," in an entrenched position.

The front faces are 45 yards, and the side faces (or flanks) 30 yards in length.

The work represented in Fig. 225 in the right half of the plate has a parapet 9 feet thick, only proof against light field artillery, with an earthen parapet at the gorge 3 feet thick and 6 feet in height.

The casemates (or blindages) to shelter the garrison could in this case be made after the completion of the rest of the work: those on the faces are of the section shown in Fig. 252, Plate XXVII.

The work represented in Fig. 227 on the left half of the plate is of a more solid character. The parapets are 12 feet thick, and the gorge is stockaded. This work might be executed in 5 reliefs of 6 hours each.

The casemates (or blindages) would have to be constructed at the same time as the rest of the work, and have the section shown in Fig. 251, Plate XXVII.

Cover is afforded to the guns to keep them protected till the last moment, when they may be required to repel an attack, and to avoid having them exposed to the preliminary fire of the enemy.

In each work the command of the parapet is $7\frac{1}{2}$ feet.

CHAPTER V.

DETAILS OF FIELD WORKS.

Embrasures, *different kinds, construction, advantages, defects.*—Mantlets, *use of.*—Gunbanks: *object, nature, &c.: Construction for one or more guns, on a straight face, or at a salient.*—Gun Recesses *with gun-banks.*—Bonnettes, *use of: advantages of gun-banks.*—Ammunition Recesses.—Powder Magazines: *rectangular and triangular, or lean-to.*—Traverses: *splinter-proof; to cover from enfilade fire; to cover from reverse fire; to protect entrances.*—Field Casemates: *where used and how made; different sorts.*—Splinter-Proofs: *how made and where used.*—Timber Work *for field constructions.*—Gun Platforms, *those in ordinary use.*—Barrier Gates.—Bridges (*and other roads*) *over the ditches of field works; use of rack-lashings.*

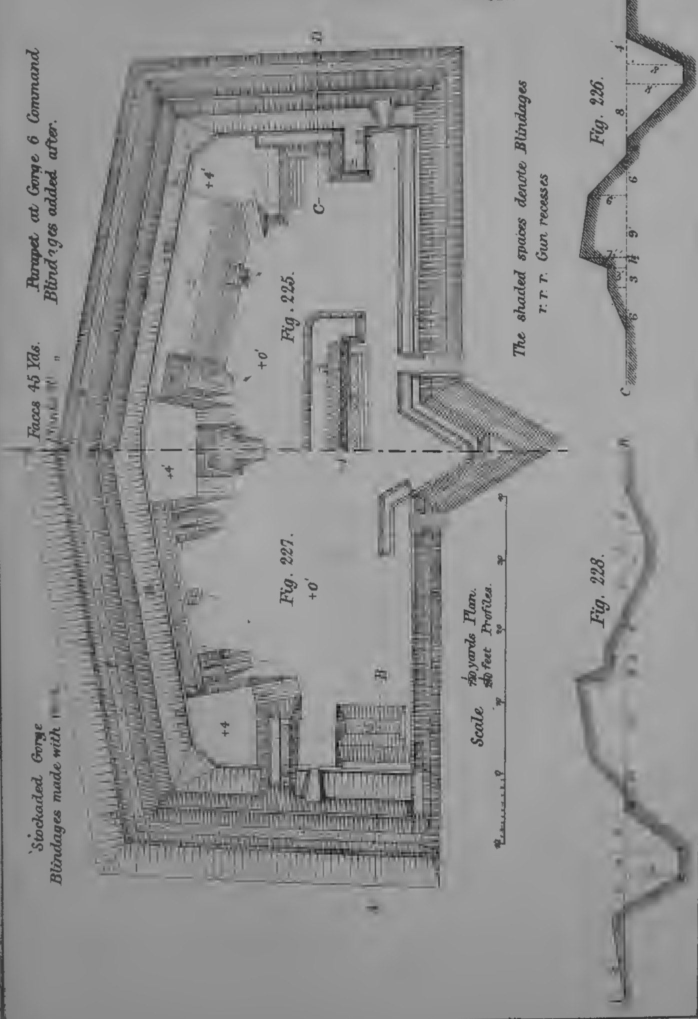
Service of Artillery in Field Works.

252. When guns are used in field works, they are fired from behind a parapet in one of two ways—either through openings made in the parapet, termed *Embrasures;* or over the parapet (*en barbette*) by means of *Gun-banks.*

253. The different kinds of embrasures are shown in Figs. 229—233, Plate XXV., at A and B.

An Embrasure is termed *direct* when its *line of fire*, or central line, is perpendicular to the line of parapet. Both the embrasures shown in Fig. 230 are direct ones. An *oblique* embrasure has its line of fire, or central line, inclined to the parapet.

FIELD REDOUBT FOR HALF BATTALION.



or a fascine, so as to catch the wheels when running up the guns for firing, just before they touch the interior slope. This is called a *Hurter*.

257. Guns on field carriages fire over a height of 3½ feet above the ground on which they rest*; while those mounted on garrison carriages fire over a height of only 2¼ feet. When embrasures are constructed for these latter, the sill is not made 2¼ feet above the level of the ground, but is usually fixed at the same height above the ground as for a gun on a travelling carriage, viz., 3½ feet; and the terreplein in rear of the embrasure is then raised up to within 2¼ feet of the sole, by a *Gun-bank*.

This is necessary to avoid having a cheek to the embrasure higher than 4′. If this height be exceeded, it becomes extremely difficult to give sufficient support to the cheek. For this reason it will become necessary, when embrasures are made in parapets having a greater command than 8′, to fix the sill 4′ under the crest, and to raise the terreplein behind to within 2¼′ or 3½′ of the sill, according to the nature of the gun-carriage used.

258. The embrasures just described, the soles of which slope down to the front, whether direct or oblique, are termed *Sloping embrasures;* but when guns are required to fire always with an elevation, as in indirect firing, the sole slopes up to the front, and the parapet thereby is less weakened and the interior of the work less exposed. An embrasure of this construction is termed *Countersloping*.

A countersloping embrasure evidently has the defect of preventing the ground in front of the work being exposed to the fire of the gun. It is therefore seldom used in field works, but is often used in siege batteries.

The embrasures shown in Fig. 230 would be thus designated—

At A...No. 1. *Direct sloping* embrasure.
,, B...No. 2. *Direct countersloping* embrasure.

259. Embrasures in general have the defects of weakening the parapet and of limiting the lateral range of the guns; they also act as funnels for the passage of projectiles, and expose the interior of the work to a certain extent; also they notify to an enemy the positions of the guns, and, if the gun be disabled, the gun portion of the parapet cannot be utilized for infantry; but they give better cover to the gunners than gun-banks, more especially from oblique fire.

They are applicable in cases where the guns are required for a specific object, such as enfilading a road, pass, bridge, &c., or for flanking ditches and intervals between works, where only a limited lateral range is required.

260. To protect the gunners from rifle bullets or splinters of shells entering the embrasure, the necks may be closed by shutters or mantlets. These may be made of wood, or iron plate, or rope in two or three thicknesses, and supported by a frame fixed to the interior crest.

Embrasures may also be "*blinded*" by placing beams or rails across from cheek to cheek, and covering them with filled sand-bags.

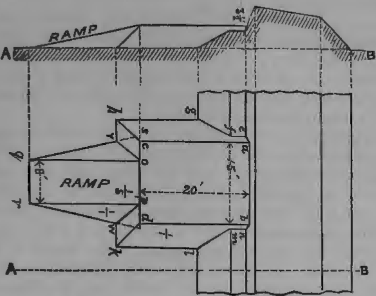
261. A *Gun-bank* is a raised platform of earth, sufficiently high to allow a gun being worked on its upper surface or *terreplein*, and fired over the crest of the parapet. The gun is then said to be fired "en barbette."

Gun-banks may be made for any number of guns, and may be constructed either behind the face of a work or at the salients. The salients are the most usual and natural position for gun-banks, as from them a wide lateral range is secured, and a better view of the surrounding country is obtained than from the re-entering parts, more especially when works occupy the top of rising ground.

The terreplein of a gun-bank for a single gun (Figs. 234, 235) should be 15 feet broad and 20 feet long, when ordinary field guns are used. These dimensions may be increased, if guns of position are used, to 20 feet broad and 24 feet long. In all cases the terreplein of a gun-bank should be level; for, if given a slope to

* Unless provided for "*overbank fire*," as in Plate II., in which case they can be fired over a height of 6 feet.

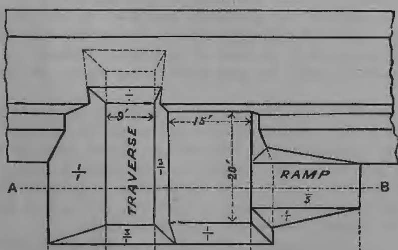
check the recoil of the gun, the gunners will be too much exposed. As a field gun fires over a height of 3½ feet, the terreplein of a gun-bank for field artillery should be 3½ feet below the crest of the parapet.



FIGS. 234, 235.—Scale $\frac{1}{300}$.

262. Figs. 234, 235 show a profile and a plan of a gun-bank for one gun, behind a straight line of parapet; the slopes of the sides and end are drawn at 45°, or $\frac{1}{1}$: the parapet is 7½ feet in height, with its interior slope at $\frac{3}{1}$. In drawing the gun-bank, the front line of the terreplein, *a b*, is made parallel to the crest, and distant from it $\frac{3\frac{1}{2}}{3} = 1' \ 2''$, and is 15 feet in length. *c d* is drawn parallel to *a b*, and 20 feet distant; *a c* and *b d*, being drawn perpendicular to *a b*, complete the rectangle forming the upper surface or *terreplein of the gun-bank*. To draw the plan of the slopes, *e f* and *m n* are made parallel to the sides, and one

FIG. 241.—Scale $\frac{1}{300}$.



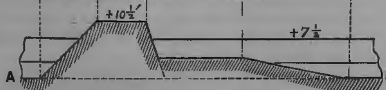


FIG. 242.—Section and elevation on A B.

foot from them, as the terreplein of the gun-bank is $4\frac{1}{2} - 3\frac{1}{2} = 1$ foot above the banquette: for a similar reason, as the terreplein of the gun-bank is in this case $7\frac{1}{2} - 3\frac{1}{2}$, or 4 feet above the ground, *g h*, *h k*, and *k l* are each drawn parallel to the lines *a c*, *c d*, and *d b*, and 4 feet from them.

263. A RAMP, or inclined road, is necessary with a gun-bank to take the gun up or down. Its breadth for a field gun should not be less than 8′; its slope may vary from $\frac{1}{4}$ to $\frac{1}{8}$; but when great heights are to be ascended, and heavy guns to be moved up—as is the case in fortresses—ramps require a gentler slope than the above, and are given a slope of $\frac{1}{10}$ or $\frac{1}{12}$.

The ramp shown in Fig. 235 is 8 feet broad; its slope is 1 in 5, and its sides slope at $\frac{1}{1}$. To draw it, the lines *o q* and *p r* are drawn 8 feet apart; its length *o q* will be $4' \times 5 = 20'$: therefore *q r* is 20 feet distant from *o p*. The plan of the sides is obtained thus: set off $o\,s = 4'$ (the height of point *o* above the ground); join *q s* to obtain *q v*, which fixes the point *v*; then join *v o*. Repeat this operation on the other side to obtain the lines *r w* and *w p*.

264. When a gun-bank is constructed on a face which is exposed to enfilade fire, it should be protected on its exposed side by a traverse of the proper thickness and height above the terreplein, and the ramp may then with advantage be placed on the side of the gun-bank, for security from the enfilade fire. Fig. 241 shows in plan a gun-bank and traverse thus constructed; the slope of the side of the traverse that is exposed to fire is drawn at $\frac{1}{1}$; the other slopes of the traverse at $\frac{3}{1}$, in order to save interior space. The slopes of the sides of the gun-bank and of the ramp are all made $\frac{1}{1}$ in the illustration. The traverse may be continued to the front, as shown by the dotted lines, if oblique fire is feared.

265. In Figs. 236—238, Plate XXV., a gun-bank for one gun on a straight parapet, together with excavations, forming *gun recesses*, on each side, are shown in detail. The earth from the gun recesses supplies that required for the gun-bank.

In the left gun recess is shown an *ammunition recess*, in which the limber boxes of the gun can be placed.

A ramp leads down to each gun recess, being cut out of the earth. A breadth of 7′ for a *cut-out* ramp is sufficient for guns.

The protection to the gun while in the gun recess is illustrated in the section, Fig. 238.

When gun recesses are provided, the guns can remain in them until the moment when they are required to act; they are then taken up the ramps to the terreplein of the gun-bank.

When gun recesses are not provided (as in Figs. 235, 248, Plate XXVI.), the guns would be kept off the gun-banks and close to the parapets until their action is required. Although less perfectly screened in this case, still considerable protection would be afforded, as there is nothing to indicate to an enemy the position of a gun-bank until he gun itself is run up to the terreplein, ready for action.

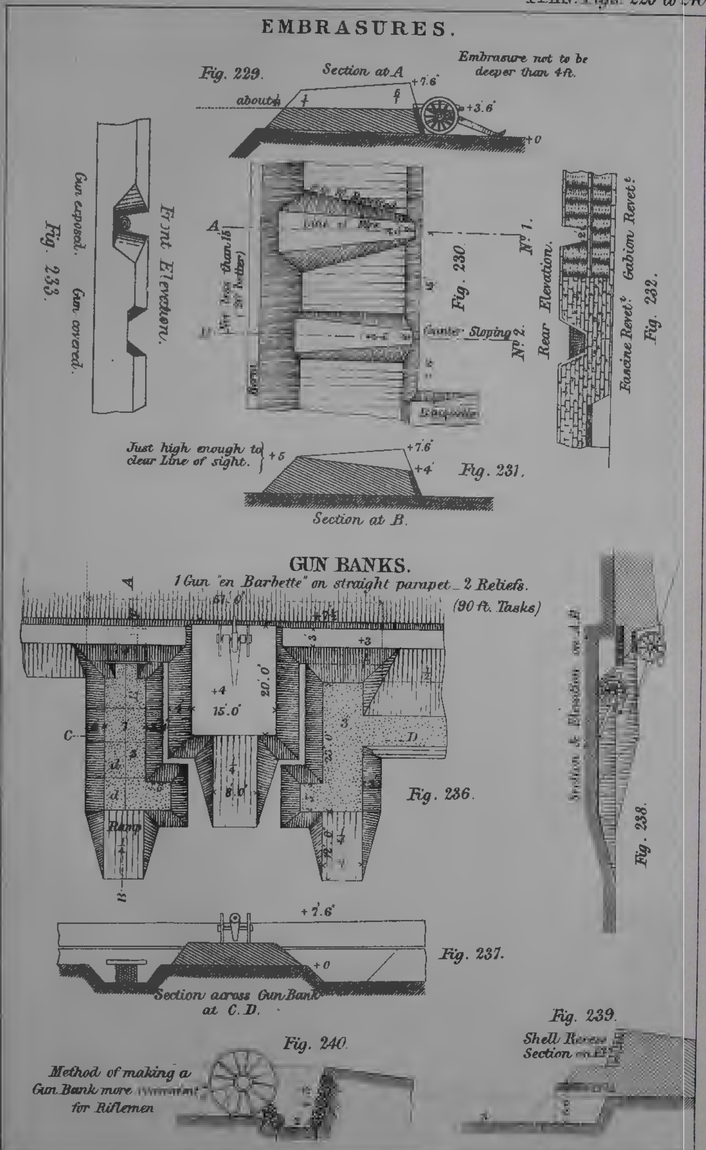
266. A *Gun-bank* for one gun in a salient is shown in Fig. 243, Plate XXVI., to enable the gun to fire over each face as well as on the capital. It is made by forming the "pan coupé," *a b*, at the salient, 15 feet long (it may vary from 6′ to 15′) to suit the fire on the capital; and by giving a length of 15 feet in addition on each face, *a c* and *b d*, for the fire over such face. The terreplein is completed by drawing perpendiculars, *c e* and *d f*, 20′ long at the extremity of each face, and by joining ends *e* and *f* of these lines.

The ramp in Fig. 243 is made on the capital, and is drawn with a slope of $\frac{1}{4}$. The sides of the gun-bank and of the ramp are all at a slope of $\frac{1}{1}$.

The ramp is here shown on the capital, but if required it might be placed at a side, similarly to that shown in Fig. 241.

In Fig. 243, a *gun recess* and a *powder magazine* at M are shown on the left of the gun-bank, and a *field casemate* under the right side; these are referred to under their own headings.

267. *Gun-banks for three guns at a salient* are shown in Figs. 248, 249, Plate XXVI. In each case, 15′ is given for the *pan coupé*, and 25′ in addition along each face for the length of terreplein, the breadth of which is 20′, as marked. Two ramps are drawn for each case, it being desirable to have more than one ramp for three guns. In Fig. 248 the ramps are placed parallel to the faces; but in Fig. 249, where *gun recesses* are shown, the ramps are, for convenience, made parallel to the capital.


EMBRASURES.
Fig. 229.
Section at A
Embrasure not to be deeper than 4 ft.
about ¼
+7.6"
+3.6"
+0
Front Elevation.
Gun exposed.
Gun covered.
Fig. 233.
Fig. 230
No. 1.
No. 2.
Sloping
Berm
Rear Elevation.
Fascine Revett.
Gabion Revett.
Fig. 232.
Just high enough to clear Line of sight.
+5
+7.6"
+4'
Fig. 231.
Section at B.
GUN BANKS.
1 Gun "en Barbette" on straight parapet _ 2 Reliefs.
(90 ft. Tasks)
+4
15.0"
20.0"
Ramp
Fig. 236.
Fig. 238.
+7.6"
+0
Fig. 237.
Section across Gun Bank at C. D.
Fig. 239.
Shell Recess
Fig. 240.
Method of making a
Gun Bank more
for Riflemen

The dimensions given to the above gun-banks enable the gun at the salient to be fired either over the pan coupé, or (as shown in Fig. 249) over either face, as may be required.

268. *Gun-banks* have the advantage of affording a wide lateral range, while they do not weaken a parapet, as is the case with embrasures. They can also be used by infantry, and, as before stated, they do not indicate to an enemy the position of the guns; but they expose the gun detachments very much.

They are especially suitable for the salients of works where a wide field of fire is afforded both to the front and over the intervals between works; and for this reason they are usually placed at the main salients, and at the shoulder angles of redoubts, &c.

269. Gun-banks may be provided with cover from musketry fire by building on the crest of the parapet a thin wall of sand-bags, the joints of which should not be broken. Some of these can easily be removed, when required, to allow the gun to fire through. *Bonnettes* may also be used between the guns for a similar purpose, but at the cost of lateral range. A bonnette is merely an increase of height given to the parapet by prolonging upwards, for a height of 3 or 4 feet, its interior and exterior slopes; it is, in fact, a sort of *traverse* built on top of a parapet.

In Fig. 244, Plate XXI., the large traverse there shown is continued towards the front of the parapet as a *bonnette;* also (by dotted lines) in Fig. 241.

Gun-banks of all kinds may be rendered more convenient for infantry by preparing the front of their terreplein in the manner indicated in Fig. 240, Plate XXV., where a small trench 2′ broad and 9″ deep is made along the foot of the interior slope, revetted on the side nearest to the gun by fascines, to act as a *hurter*, and to prevent the gun wheels from breaking the earth away.

270. *Gun Recesses*, already referred to, and illustrated in Figs. 236-7-8, Plate XXV., and Figs. 243, 249, Plate XXVI., are excavations made for the purpose of screening guns, until they are required to enter into action. In the examples given they afford some of the earth required for the gun-banks, as well as provide the cover wanted. They, and also the cut-out ramps leading down to them, should be 7′ broad.

271. *Ammunition Recesses* should be made in works close to the guns they are required to serve. Suitable positions are afforded, as shown in Plates XXV. and XXVI., under the banquette and the gun-banks.

A breadth and depth of 4 feet, and a height of 4½ feet (for two tiers of limber boxes), may be given to them.

272. *Powder Magazines* in field works are not often required to be of large dimensions; it is usual to provide small magazines to supply a couple of guns somewhere near the pieces, either in the infantry casemates, or in traverses (Fig. 266, Plate XXVIII.), or under gun-banks (as at M, Fig. 243, Plate XXVI.), close to the parapet, so as to be secure.

The position of a magazine should also allow it to be easily drained. There should be an entrance passage leading to the magazine, the body of which should be clear of the prolongation of the passage.

Magazines have usually one of two shapes *in profile:* either they are "rectangular," as shown in Figs. 246, 247, Plate XXVI., and Fig. 266, Plate XXVIII., or they are "triangular," or "lean-to," as in Fig. 267, Plate XXVIII.

273. *Rectangular Magazines* (Figs. 243–6–7, Plate XXVI., and Fig. 266, Plate XXVIII.) are preferable to others, on account of their convenient shape for stowage. They should be 4′ (or more) broad, 5′ in clear height, and are usually 10′ or 12′ long.

Their sides may be lined with *frames* and *sheeting*, or with gabions and fascines.

The roof should be of strong timbers or of iron rails, and covered with at least 4 feet of earth.

If exposed to direct fire (which is very unusual) they should have 15′ or more of earth on the exposed side.

274. *Lean-to or Triangular Magazines* (Fig. 267, Plate XXVIII.) may be formed by laying stout timbers, about 10″ × 6″ at an angle of 50° or thereabouts, against the revetted (and presumably safe) side of a traverse, &c. These beams should be covered with two feet of earth, and a tarpaulin laid over all to keep off wet. A floor of planks may be provided, if necessary. One end of the magazine should be closed by a sand-bag (or other) wall, and the other end provided with a rough door. The magazine should be drained.

The facility of construction of this magazine is its great recommendation; it is evidently inconvenient for stowage.

275. Traverses are mounds of earth of various dimensions, built where required as a protection from various kinds of fire.

When made only of sufficient thickness to arrest splinters of shells, they are termed *Splinter-proof Traverses;* and when made as a protection from reverse fire, they are termed *Parados.*

276. A *Splinter-proof Traverse* is shown in profile in Fig. 250, Plate XXVI. It should be 4′ thick at top, 6 feet or more in height, and its sides should be revetted in order to save space. When guns are placed close together behind a parapet, it is usual to place splinter-proof traverses between the guns: in this case, a passage 2′ broad should be left between the traverse and the parapet, to allow men to get round either end, in case of a shell falling among them. The usual length is 16 feet, so as to project 18′ to the rear of the parapet, and therefore behind the tail of the gun platforms.

277. When traverses are exposed to fire, their exposed side should not be revetted, and they must be made of the proper thickness at top to withstand the fire expected. This will vary from 6′ to 12′, or even more. In many cases traverses can serve defensive purposes; they would then be provided with a banquette.

278. *Traverses to protect from enfilade fire* a line of work are shown in Fig. 244, Plate XXVI., and on each flank of the redoubt shown in Plate XXIV.

In each case the traverse should join on to the parapet; and its length, perpendicular to the parapet, should be sufficient to protect the terreplein occupied by the guns, &c., requiring to be screened. The height is sometimes the same as that of the parapet, as in Fig. 225 on the right flank in Plate XXIV., where it evidently is invisible to an enemy; whilst in other cases, as in Fig. 227 on the left flank of Plate XXIV., in Fig. 241, and in Fig. 244, Plate XXVI., the height is 3′ or 4′ greater than that of the parapet, across the top of which the traverse is carried, in the form of a bonnette, to increase the amount of protection afforded.

When traverses of this great height are made, they may be formed with magazines inside them, as in Fig. 266, Plate XXVIII., or they may be provided with *Field Casemates* (Art. 284) on their secure side, as in the left flank of Plate XXIV., and in Fig: 244, Plate XXVI. By thus making use of them, not only is a double purpose fulfilled by the traverses, but the amount of earth required for their construction is lessened.

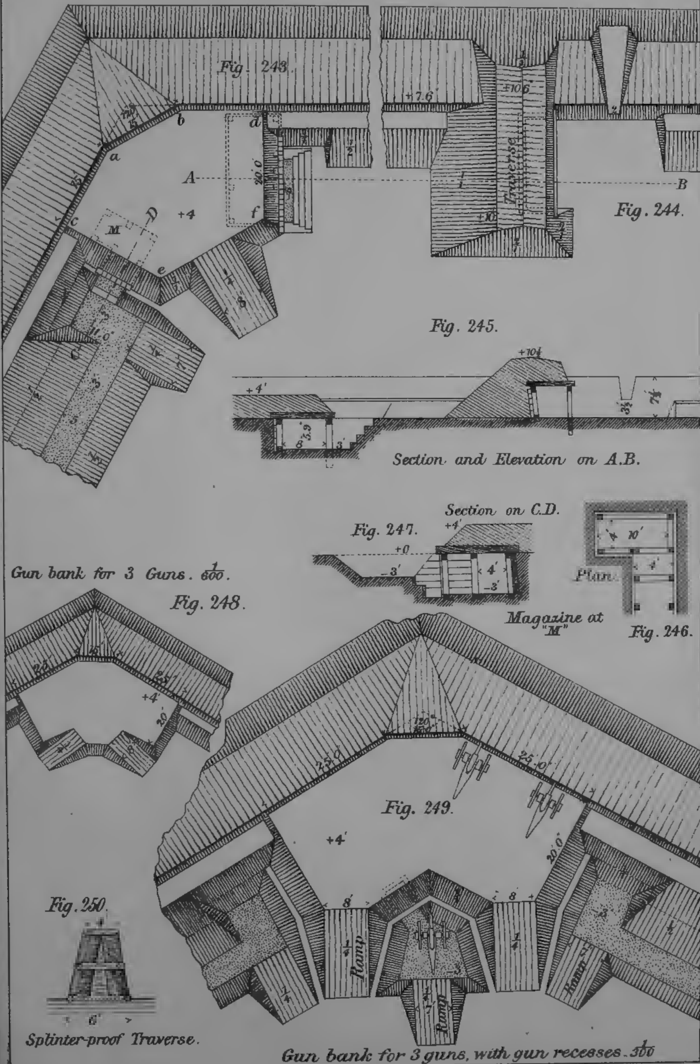
279. An earthen traverse to cover the entrance into a work is required when the entrance is liable to artillery fire. See Fig. 261, Plate XXVIII. This traverse should be of the same profile as the parapet, and between it and the banquette there should only be the width necessary for the roadway (7′ for guns). The length of the traverse should be sufficient to intercept shot passing into the opening in the most oblique direction possible, which is when the opposite sides of the entrance are *both* grazed by the same shot.

280. The dotted lines $a\ b$ and $k\ f$ (Fig. 261, Plate XXVIII.) represent lines of fire passing through the opening (7′ broad for guns) in the most oblique direction possible at $4\frac{1}{2}$′ above and parallel to the ground. The line of fire $a\ b$ in plan grazes the exterior slope at c, the interior slope at d, and strikes the traverse at b; the similar line of fire $k\ f$ strikes the traverse at f. The traverse should be made to extend 4′ further than the points b and f, and being for defence, is provided with a banquette.

It will be seen that, owing to the parapet on the left of the entrance having

GUN BANKS, EMBRASURES, TRAVERSES.

Gun bank and embrasure with traverse and field casemates in a flank exposed to enfilade fire.



been thickened, the traverse does not extend so far on the left as it does on the right, *i.e.*, that *h f* is less than *h b*.

281. When the entrance is placed at a re-entering angle, the traverse is often connected with the parapet, as shown by the dotted lines : the traverse would in this case be terminated 4′ beyond the point *f*, as before.

In most cases of redoubts or other separate works, the entrance, being on the rear side of the work, would be exposed only to musketry fire from its front. In such cases a musket-proof traverse may be made of stockade work, as in Fig. 262, Plate XXVIII., and would occupy but little interior space. The actual entrance should be closed by chevaux-de-frise, or other movable obstacle.

282. *Parados*, or traverses for protection from reverse fire, are shown in detail in Plate XXIX. They are necessarily large masses of earth, as they are required to protect men, when *on the banquettes* of exposed parapets, from reverse fire.

Passages should be made through them for facility of communication, and they afford a secure position for magazines and field casemates, on account of their great thickness at the base. They are further referred to in the chapter on "Defilade."

283. Cover for Troops from hostile fire should be provided in the interior of works to as great an extent as possible. When this is properly effected, the defenders can be kept in safety during the cannonade which is the usual preliminary to an assault, and are in readiness to man the parapets at any required moment. Either *Field Casemates* or *Splinter-proofs* are used for this purpose (Plate XXVII.).

284. *A Field Casemate* is a shell-proof chamber, of which the walls are of timber and planks or fascines, and the roof is formed of stout timbers (or iron rails) covered with 4 feet or more of earth : this renders them proof against the shells of field guns.

Their breadth should not be less than 8 feet, if a guard-bed is required inside : the clear height ought not to be less than 6 feet.

The entrance to field casemates, when sunk in the ground, may be by steps, or by ramps at intervals, as in Plate XXIV., and Fig. 253, Plate XXVII., or extending the whole length of the casemate, as in the keep shown in Figs. 223, 224, Plate XXIII. This latter arrangement is best, as it affords no cover to an enemy from the fire of works in rear, should he capture the casemate.

In Fig. 244, Plate XXVI., the floor of the casemate under the traverse on the right is made on the level of the ground, which can be done owing to the height of the traverse. The casemate is also quite open to the rear.

Casemates are usually placed under the front parapets of a work, as in Plate XXIV. and Figs. 251, 252, Plate XXVII., or under the secure sides of traverses, as in Plate XXIV. and Fig. 244, Plate XXVI., &c., in order to profit by the earth cover afforded.

They may also be placed in the interior of a work (as in Fig. 225 on the right of Plate XXIV., or in section, Fig. 253, Plate XXVII.), to cover the reserve in the work, in an excavation, the earth from which is used for the required cover overhead and in front. This latter mode would be resorted to, in order to cover any supporting troops outside works.

Fig. 251, Plate XXVII., represents a good field casemate to be constructed simultaneously with the parapet.

Fig. 252 of the same plate shows one that may be made either simultaneously with the parapet or afterwards.

285. *Splinter-proofs* are a rough kind of casemate, proof only against the splinters of shells. They are usually "lean-to" structures, similar to the magazine described in Art. 274, and shown in Fig. 267, Plate XXVIII. Their roof is made of beams and planks, covered with 1 foot or more of earth.

They may be made on the revetted sides of traverses or, as shown in Fig. 254, Plate XXVII., immediately behind a parapet.

286. *Timber Work.*—In constructing timber work for casemates, magazines, &c., the materials should be as far as possible prepared under cover, and the work should commence the moment the diggers clear out of the excavations. The timbers may be connected together, either by mortice and tenon, Fig. 257, Plate XXVII., like ordinary house carpentry, or by iron spikes and dogs, as in Fig. 258. The former method is more durable, and answers for work done at leisure; but the latter is the better and quicker method for work done in the field, and does not require so much skill.

The uprights or *stancheons* which support the roofs may either be sunk about 3′ into the ground, as in Fig. 256, or they may rest, as in Fig. 255, on a piece of timber laid on the ground, and called a *ground-sill*, being secured thereto by *dowels*. The former mode is the stronger, and requires less strutting when the ground is hard; but the latter is better in soft soil, and on the whole is to be preferred for rapid work.

The stancheons are usually 10 to 12 inches square or in diameter, and about 6 feet apart; but much depends on the material actually available.

When iron rails are used for roofing purposes, they may be arranged as shown in Fig. 260, Plate XXVII.

287. *Gun Platforms.*—Platforms may be required for field guns, when they are frequently fired from the same spot.

A regular gun platform consists of a floor of stout planks resting on beams, termed *sleepers*, underneath. Such a platform, termed a *ground platform*, is shown in Fig. 269, Plate XXVIII.

The platform is 15′ long by $10\frac{1}{2}$′ broad, and is laid with a rise of $\frac{1}{24}$ to the rear to check recoil. The *sleepers* are 5 in number: the centre one is laid in the line of fire produced, the others at equal intervals over the breadth of the platform. Earth is well rammed between the sleepers. The planks are then laid on the sleepers, and are secured to them either by iron spikes, or by a *riband* and *rack-lashings*, as described in Art. 291 on "bridges across ditches of field works."

Similar platforms suitable for field guns can be made of rough material by laying five sleepers of rough-sawn timber, or flooring joists from houses, and roof timbers, or straight trees about 5″ diameter and 15′ long. Across these may be nailed 3″ planks cut to $10\frac{1}{2}$′ lengths.

288. *Plank Runners.*—For firing in one direction only, a platform sufficient for a field gun may be made, as shown in Fig. 268, Plate XXVIII., with three stout planks, one of which is laid for each wheel to recoil along, and the third for the trail. These planks should be firmly secured by stout pickets driven on either side and at their rear ends, as shown in the figure.

The recoil of the gun can be checked by large wedges, or inclined planes, of wood, laid on these planks to catch the gun wheels.

289. *Barrier Gates* are required to close openings of various kinds into works. If guns or carts are required to pass, the gate should have a clear width of opening of 7 feet; if for Infantry only, a width of 4′ will suffice.

The gate should be musket-proof and loopholed. Such a gate, when closing the entrance into a work, would, if not exposed to artillery fire, supersede the necessity of an earthen traverse inside, and would thus save interior space.

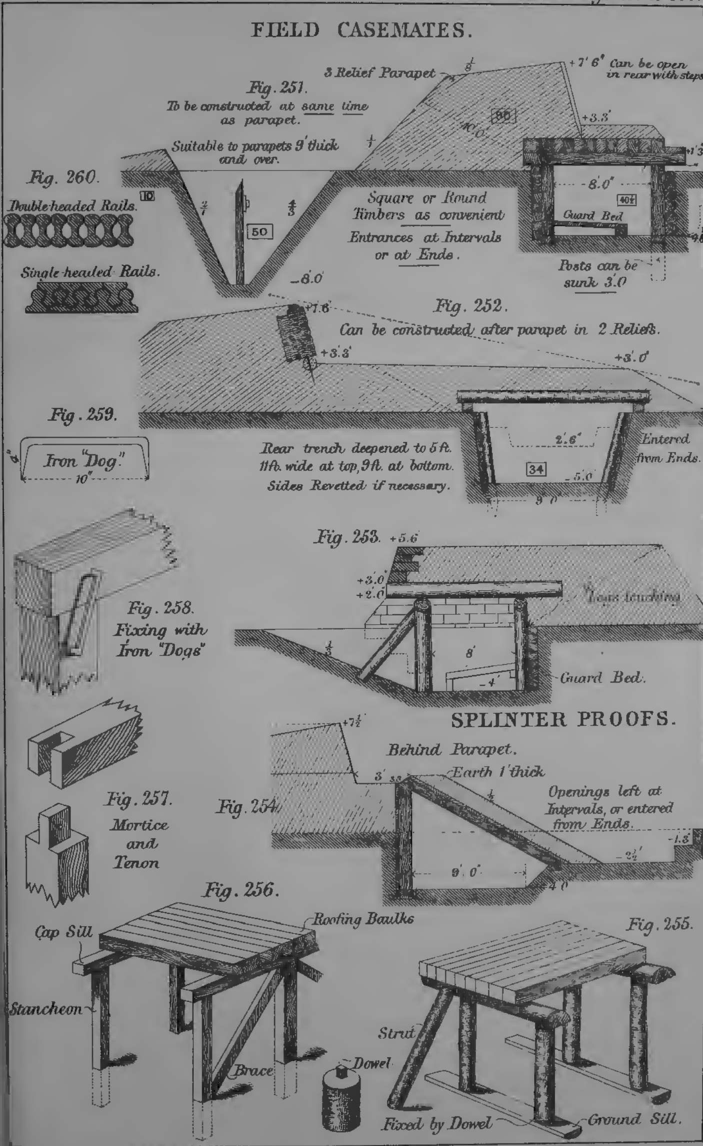
Barrier gates should open outwards.

Chevaux-de-frise makes a good hasty barrier. It should be of the same length as the clear breadth of opening, and secured at each end by chains to posts, so that it can be moved on one side when required.

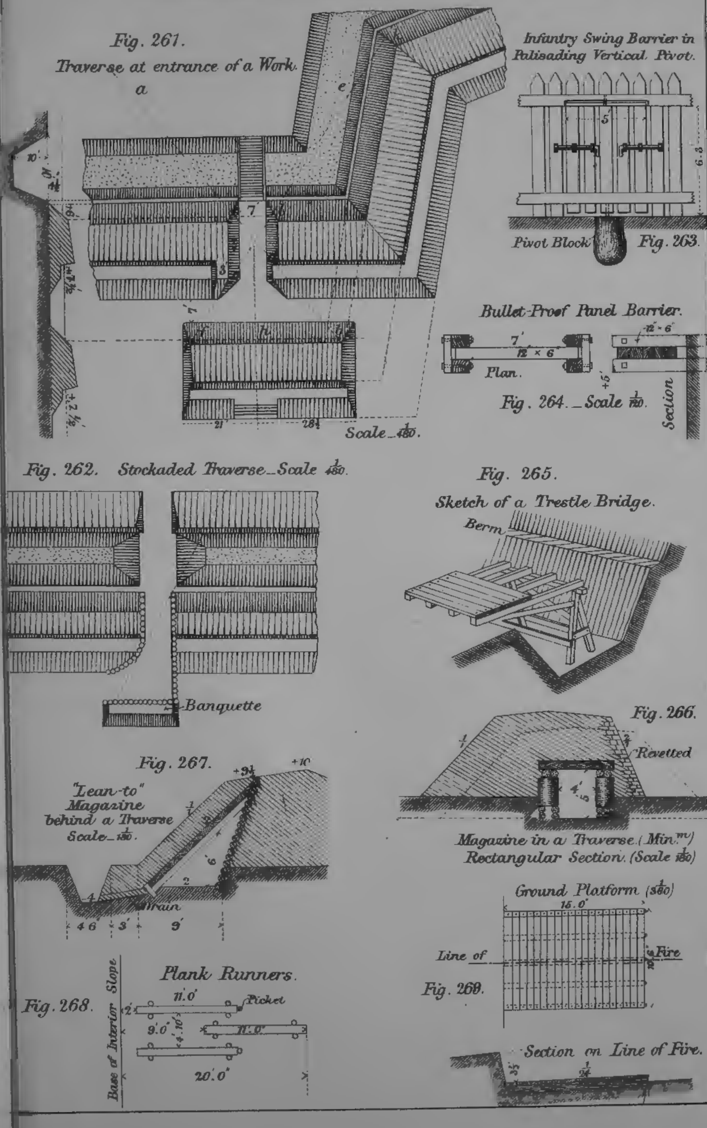
A gate suitable for Infantry through a line of palisades is shown in Fig. 263, Plate XXVIII. It is composed of a single leaf formed of 5 palisades, and turns on a central pivot.

Fig. 264 shows a movable bullet-proof barrier composed of baulks slipped successively into side grooves.

290. *Roads across ditches of works.* In some cases, as shown in Fig. 262, Plate XXVIII., a piece of the natural ground, about 10′ broad, can be left in the ditch to serve as a roadway; the entrance should then be guarded by movable obstacles, such as chevaux-de-frise.


FIELD CASEMATES.
Fig. 251.
To be constructed at same time as parapet.
Suitable to parapets 9' thick and over.
3 Relief Parapet
+7' 6" Can be open in rear with steps
+3.3'
Square or Round Timbers as convenient
Entrances at Intervals or at Ends.
-8.0"
Guard Bed
Posts can be sunk 3.0
-8.0
Fig. 260.
Double-headed Rails.
Single-headed Rails.
Fig. 252.
Can be constructed after parapet in 2 Reliefs.
+1.6
+3.3
+3.0
Fig. 259.
Iron "Dog."
10"
Rear trench deepened to 5 ft. 11 ft. wide at top, 9 ft. at bottom. Sides Revetted if necessary.
2.6"
-5.0
Entered from Ends.
Fig. 253. +5.6
+3.0
+2.0
8'
-4'
Guard Bed.
Fig. 258.
Fixing with Iron "Dogs"
SPLINTER PROOFS.
Behind Parapet.
+7½
Earth 1' thick
Openings left at Intervals, or entered from Ends.
Fig. 254.
9'. 0"
-1.3
-2½'
-4.0
Fig. 257.
Mortice and Tenon
Fig. 256.
Cap Sill
Roofing Baulks
Stancheon
Brace
Dowel
Fig. 255.
Strut
Fixed by Dowel
Ground Sill.

TRAVERSES, MAGAZINES, PLATFORMS, BARRIERS.



With shallow ditches, a ramp may be made down into the ditch and up into the work.

With larger ditches, bridges are required. Such a bridge is shown in Figs. 261, 265, Plate XXVIII. The roadway of planks (2″ thick) rests on long beams termed *baulks*, which themselves rest on the escarp and counterscarp; their ends should be supported underneath by a *sleeper*. The baulks should be 5″ or 6″ broad and 8″ or 10″ deep.

A small beam, termed a "riband," 4″ square (not shown in Fig. 265), is laid along each side of the bridge, and is secured firmly to the baulks underneath, thereby keeping the planks fixed.

The "riband" in a bridge has the two-fold object of keeping the planks in position, and also of preventing the wheels of vehicles slipping over the side of the bridge. The width of roadway *inside the ribands* should be 7′ or more for guns to cross.

In ditches wider than 12 feet the baulks should be supported midway by a trestle resting on the bottom of the ditch, as in Fig. 265, Plate XXVIII.

The portion of the bridge nearest to the work should be easily removable so as to permit of a gap being formed, as shown in the figure. The bridge can be completed in a few minutes.

291. The ribands should be secured to the baulks, at intervals of about 4 feet, by *rack-lashings* (Fig. 270).

A rack-stick and lashing consist of a wooden pointed stick 1½′ or 2′ long, to which is secured about 8′ of rope. To use it, the end of the rope is passed through an opening in the planks (made for the purpose), brought round the baulk and riband, and then formed loosely into a loop, as shown in Fig. 270. The point of the stick is then inserted into the loop, which is twisted round by means of the stick used as a lever, as tightly as possible, after which the point of the stick is jammed between the rope and the riband on the outside of the roadway. When this is done throughout the length of the bridge, the latter is said to be "racked down."

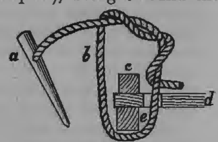


FIG. 270.

a. Rack-stick.
b. Lashing (loosely tied).
c. Riband.
d. Plank.
e. Baulk.

By means of this simple method great rigidity is obtained. The fastenings can be quickly made and unfastened, or tightened up, without damaging the timber, as would be the case were nails or screws used. It is particularly applicable to a movable bridge.

CHAPTER VI.

DEFILADE OF FIELD WORKS.

DEFILADE, : *its object: cover from view and from fire; modes resorted to for obtaining it.*—PLANE OF DEFILADE *and* TANGENT PLANE : *method of practically determining the command for a given case; favourable slope to occupy when works are commanded.—How to defilade* OPEN WORKS *from a single commanding hill, or from two hills, or a range of hills.—Use of* PARADOS.—DEFILADE OF CLOSED WORKS : *principles to be followed; necessity for parados, even where works are not commanded; example of Prussian Redoubt before Paris in* 1870–71.

ADDENDA.—*Examples of Calculations in Defilade.*

292. DEFILADE is the art of determining the heights to which the different covering masses of defensive works must be raised, in order to obtain the required cover for the defenders from an enemy's fire.

Defilading is only necessary to be resorted to when the site of the work is disadvantageous with reference to the enemy's position; in fact, when it is commanded: this is the case whenever the *plane of site of the work, if produced, passes below the ground within range, which can be occupied by an enemy.*

This disadvantage of site usually occurs when works occupy low ground with higher ground in front (such as is the case with bridge heads), but it will also occur when works occupy higher ground than that able to be occupied by an enemy, if the ground behind the parapet rises sufficiently towards the rear to produce the case quoted above in italics.

293. On ground that is practically level, a command of 8 feet is usually assumed as the minimum necessary to cover the defenders, standing on the natural surface of the ground, for a *moderate* distance in rear of the parapet, provided the enemy be unable to occupy commanding ground.

This command of 8 feet gives *cover from view* for an indefinite distance in the rear, but it only *covers from fire* until the enemy's projectiles, which may have passed over the crest of the parapet, arrive within 6 feet (the assumed height of the defenders) of the ground.

The extent of ground thus covered from fire *cannot be exactly determined*, partly owing to the varying angles of descent of projectiles fired at various ranges,* and partly to the fact that while some of the hostile fire is frontal, much of it will be oblique, which is evidently more searching, and is sufficient to account for some of the casualties that happen in the best regulated field works.

294. It is not practicable to protect the whole of the interior of field works from the indirect and curved fire of artillery, such as is brought to bear for some considerable time previous to an assault: while such fire lasts, the bulk of the defenders must shelter themselves by remaining close behind the parapets, in the rear trenches if there are any; or in the field casemates. But it is desirable to screen the interior of the works as much as possible, and at the least to do so from view; and if this be done, projectiles at close ranges will not, owing to their very slight angles of descent, search out the interior.

295. Three methods are resorted to, either separately or in combination, in order to defilade a work, viz. :—

(1) Increase of command to parapets.
(2) Use of trenches, or of sinking the terreplein.
(3) Traverses.

A definite amount of cover behind a parapet is said to be afforded when the parapet has its crest in an imaginary plane which passes $4\frac{1}{2}'$ above the most commanding † ground, and the required height of cover above the ground in rear.

In Fig. 271, Plate XXIX., the parapet with crest at P is said to afford cover at D to the height of D above ground.

For good cover this height should be 8 feet; and it should not be less than $6\frac{1}{2}$ (unless the terreplein is lowered), otherwise the defenders would not be covered from view.

The imaginary plane before mentioned, which passes through and fixes the position of the crest of the parapet, is termed the "*Plane of Defilade*": it passes $4\frac{1}{2}'$ above the commanding ground, because that is the greatest height from which an enemy can fire, whether with musketry or artillery.

296. Evidently it is inconvenient to observe in the plane of defilade, but if we imagine a plane parallel to it, and tangent to the commanding ground, we obtain a plane very conveniently situated for observation, since it passes above the ground in rear of the parapet at a height suitable for observation, while the commanding ground itself is easily seen.

* The Martini-Henry bullet falls about 1 in 142 at 300 yards, and 1 in 90 at 500 yards.

† The most commanding point of a height is not necessarily the highest point; but it is that which *appears* the highest when viewed from the work, or, in other words, that which has the *greatest angle of elevation* with reference to the site of the work.

This imaginary plane is termed the "*Tangent Plane*," because it is tangent to the commanding ground: it may be defined as a plane parallel to, and $4\frac{1}{2}'$ under, the plane of defilade; therefore, if the height of D in Fig. 271 is 8′, that of *d* will be $8' - 4\frac{1}{2}'$ or $3\frac{1}{2}'$.

It is evident in any case, that while the plane of defilade passes through the crest of a parapet, the tangent plane (being $4\frac{1}{2}'$ below it) will pass through the banquette.

297. The following is a simple rule for practically determining the command of a parapet at any one point:—

Look from a point in the tangent plane (as *d*, Fig. 271, Plate XXIX.) to the most commanding point (e') that can be occupied by an enemy; observe the intersection p' of the visual line with an upright at P: the banquette will be at p' in the section, and the crest of the parapet at P $4\frac{1}{2}'$ above p'.

298. A line of parapet may be in one of the two positions in plan shown in Fig. 273, with reference to the ground to be protected by it, and to the general direction of the hostile fire from a single eminence in front.

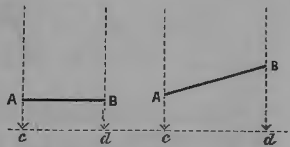


FIG. 273.

In the first case (that on the left), it is evident that the command will be the same throughout the length A B, because the distances to be covered are the same both at A and at B.

In the second case (that on the right), the command of the parapet will require to be greater at B than at A, owing to the distance to be covered at B, viz., B*d*, being greater than that at A, viz., A*c*.

The crest of the parapet would rise from the command suitable at A to that requisite at B.

In either of these typical cases, the actual command can be determined by applying the preceding rule: the point *c* in each of them will be the point of observation for determining the command at A, while *d* is the point of observation for similarly determining the command at B. The arrow marks indicate the direction of the hostile fire from the commanding ground, and therefore the direction in which to observe.

299. Fig. 274 shows a parapet on ground lower than that which can be occupied by an enemy, but owing to the favourable slope behind, which *when*

FIG. 274.

produced passes over the ground at H, the enemy at H would have no advantage of command over the defenders. Such a site as this should be carefully sought after when works are necessarily constructed facing high ground.

300. An open work, such as a Redan or a Lunette, should be defiladed as far as its gorge.

If the work be *commanded by one hill in its front*, its interior defilade will be effected by placing the crests of the parapets in a plane of defilade passing 8′ (or other required height of cover) above the ground at the gorge of the work, and $4\frac{1}{2}'$ above the commanding ground.

This implies that those parapets which terminate at the gorge will have *at the gorge end* a command equal to the intended height of cover, which for ordinary cases is assumed to be 8′.

301. If the work be a Redan (as in Fig. 275, No. 1), it will only be necessary to determine the command at one point—viz., the salient C, at which *point* it will be the same as would be *required throughout* for a line of parapet passing through C, and parallel to A B.

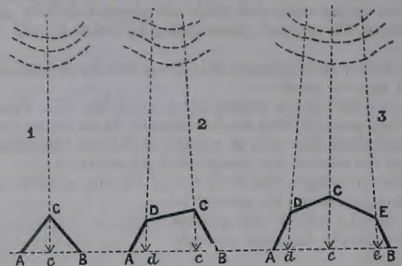


FIG. 275.

To determine this command at C, a single observation at *c* in the gorge line is all that is required.

When determined, the work would be constructed with this command at C, whence it would decline to the lesser command (equal to the required height of cover) at A and at B.

In the irregular open work, No. 2, it is evident that the command would require to be determined at two points—viz., at D and at C.

This would be done by observation at the two points, *d* and *c* respectively, in the gorge line. Each of the three parapets (A D, D C, and C B) would here require a varying command.

In the case of the Lunette, No. 3, the command would require to be determined at three points—viz., at D, C, and E, by observation from the three points, *d*, *c*, and *e* respectively, in the gorge line. The four lines of parapet which compose the work would have a varying command, but owing to the inequalities of the ground (even when apparently very regular) the command of the right face and flank would not necessarily be the same as that of the corresponding lines of parapet on the left.

302. *An Open Work commanded by Two Hills* may be defiladed by placing the crests of its parapets in a plane passing $4\frac{1}{2}'$ over each of the two hills, and 8′ (or other required height of cover) above the gorge at the end farthest from the most commanding of the two heights—provided this does not give a command greater than the maximum permissible, viz., 12′.

If *more than two hills*, or *a range of hills*, command the work, the two most commanding points should be selected, and the work should be defiladed (as above) from these two points, which will be sufficient to protect them from the others.

303. Figs. 276, 277, Plate XXIX., are pictorial sketches, showing the manner in which, if considered necessary, the tangent plane for the cases referred to above can be actually constructed.

In Fig. 276, a cord, B C, is stretched *in the tangent plane*—viz., at $3\frac{1}{2}'$ (or $8' - 4\frac{1}{2}'$) above the ground at the points *b* and *c* in the gorge, which may be about 12′ apart.

Two other cords (A B and A C), *also in the tangent plane*, are fixed by determining the height of the point A above the ground at *a*, which point is also for convenience about 12′ from *b* and *c*. This height is determined by observation from the point D in the gorge cord B C, where D A produced passes to *e*, the most commanding point.

Having fixed the point A, and keeping the three cords A B, B C, and C A taut, the tangent plane in any direction can be observed by looking along the plane of the three cords. For instance, in Fig. 272, Plate XXIX., the height of the tangent plane at *m* (the left shoulder) could be found by looking in the line *c g* from the point *c*.

304. In Fig. 277 the tangent plane for two commanding heights is fixed. The single *point* A is here fixed in the gorge at the height of the tangent plane; the heights of the other two points (C and B) of the required triangle of cords are fixed by stretching the cord B C between uprights, and moving it until, by observation from A, the points *m* and *n* in the cord are in the direction of the two commanding heights.

305. In all the foregoing cases only a single plane of defilade, and consequently a single tangent plane, has been considered. This may necessitate too great a command, and when such is the case it is usual to resort to the use of traverses in addition to the parapets, as a means of affording cover. These defilading traverses, termed *parados*,* divide the work into portions, each of which can be defiladed separately.

Fig. 278 is an illustration in section. A and B represent the rear and front parapets of a closed work. A parados is placed at C, about midway between them. The parapet at B gives cover to a height of 8′ as far as the parados, as shown by its (dotted) plane of defilade.

The parados at C has its top in a plane of defilade passing $6\frac{1}{2}'$ above the banquette (or 2′ above the crest) of the parapet A. This covers the defenders of A from being seen in reverse from E, when they are required to man the parapet. The side of the parados exposed to artillery fire from E would be left at $\frac{1}{1}$; the other side being revetted steeply to save earth, as well as interior space. Field casemates would also be placed in the parados.

306. Fig. 279 is an illustration *in plan* of such an arrangement as is shown in section in Fig. 278. Here the front parapets would require to afford cover to the interior as far as the parados, while the latter would require to defilade from view the defenders of the rear parapets when on the banquette.

To facilitate communications, the parados does not join on to the side parapets, but a passage is left at each end: this passage is protected by the short length of parados which joins on to the parapet, and which is in the same plane of defilade as the main parados. These shorter traverses are also serviceable to cover the side parapets from enfilade.

Covered passages, kept as low as practicable, would also be made through the parados.

307. Fig. 280 shows a work with a sharp salient, commanded by the two hills A and B. In this case, to prevent the faces from being seen in reverse, the parados is placed along the capital, stopping short of the salient in order to allow room for a barbette; while the portions *a e* and *e f* of the faces must be raised by bonnettes (traverses on the superior slopes) in order to close the open spaces caused by breaking the length of the traverse.

The work is defiladed by making the left front parapet afford the desired cover to the left portion of the work from the left hill; the right portion being similarly defiladed from the right hill by means of the right parapets.

The parados would require to defilade the interior as far as the gorge; the *left* portion thereof from the *right* hill, and the *right* portion from the *left* hill. If the gorge be open, the planes of defilade for the parados should pass 8′ above the ground at the gorge; but if there be a gorge parapet, the planes of defilade of the parados should pass at least 2′ above the crest—*i.e.*, $6\frac{1}{2}'$ above the banquette—in order to cover from view.

The parados, having thus two distinct planes of defilade, would be made of the greater of the two heights thus found.

* The term "Parados" means defence for the back; its derivation being similar to parapet, parasol, parapluie, &c.

The height of the *bonnettes* at *a e* and *a f* would be fixed by the planes of defilade of the parados from the heights in their front—that is, *a e* from the hill A, and *a f* from the hill B.

308. While these bonnettes, thus constructed, are sufficient to screen from view, they would not afford protection (to any satisfactory extent) from enfilade fire to the faces, or reverse fire to the flanks, from the heights A and B. There is no way of doing this except by the use of suitable traverses attached to the parapets, such as are shown in Fig. 244, Plate XXVI., or in both flanks of the redoubt in Plate XXIV.; and it must be understood that such accessories of defence, although not indicated, are carried out in Fig. 280. The outline of this work would be much improved, if other conditions suited, by making it as shown by the dotted lines: the front faces would then be secure from enfilade from the hills, while the depth of the work would be reduced, thus reducing also the necessary commands.

309. Although Parados are not usually proposed except in cases when works are commanded by high ground within effective range, it is to be borne in mind that *in every case* the side parapets of open works, and both the side and rear parapets of closed works, are liable to enfilade and to reverse fire from the front—*i.e.*, the enemy's position.

The enemy, by bringing a cross fire of artillery on to any single work, is sure to enfilade some of the faces (usually the side ones), and to take in reverse others (usually the rear faces): these conditions are altogether independent of command; so also is the *necessity for protection to the defenders*, but the amount required will vary according to the details of any case.

310. In some of the Prussian redoubts round Paris in 1871, cover for the defenders of the rear parapets from fire from the front (reverse fire) was obtained by the simple expedient of excavating a trench immediately behind the rear parapets and by throwing the earth to the rear—*i.e.*, towards the interior of the redoubt—so as to form a *parados parapet*, leaving a berm to act as a banquette. The defenders of the rear parapets, sitting in the rear trench, were thus covered from a cannonade by the parados parapet, and when required to act, they could either man the rear parapet or, if necessary, the parados parapet, over which they could pass if required to charge an enemy assaulting from the front. This case is one of imperfect protection, but it has the advantage of requiring the expenditure of an extremely small amount of labour, such as may be assumed as always forthcoming. This is not necessarily the case with the large masses of earth required for regular parados, which are very good if there is time to construct them.

311. ADDENDA TO CHAPTER VI.—EXAMPLES OF CALCULATIONS FOR DEFILADING.

Defilading is essentially a practical operation, so far as ordinary field works are concerned, and is best carried out by actual observations, as described in the foregoing chapter; but as a means of impressing the principles in the mind, a few simple examples are given, in further explanation of the text. It will, of course, be evident that if the slope of a line be given, its rise or fall in any given distance can be found; and on this simple fact are based the necessary calculations in the examples.

EXAMPLE 1.—*A line of parapet is required to give* 8′ *of cover to a distance of* 15 *yards in rear of its crest from a hill* 40 *feet in height and* 435 *yards distant from the crest. Find the necessary command of the parapet.*

Here the plane of defilade rises in the distance from R to H (450 yards) a height of $40' + 4\frac{1}{2}' - 8' = 36\frac{1}{2}'$; its rise in the distance, P R (15 yards), must then be found and added to 8′, the given height of plane of defilade at R (or cover required), to obtain the required command.

Yds.		Yds.		Ft.		Ft.	
450	:	15	: :	36·5	:	1·22	the rise of the plane of defilade in distance P R.

$\therefore$ Command of parapet $= 8' + 1 \cdot 22' = 9 \cdot 22'$ or $9\frac{1}{4}'$ nearly.

DEFILADE.


Fig. 271.
Plane of Defilade
Tangent Plane
Fig. 272.
Fig. 278.
Fig. 279.
Fig. 280.
Fig. 276.
Fig. 277.

N.B.—There is no practical advantage in determining the command of a parapet (or the depth of a ditch) to a less dimension than the nearest quarter of a foot.

Example 2.—*A line of parapet (on level ground) is to afford cover to a height of* $5\frac{1}{2}'$ *above ground to a distance of* 18 *yards behind its crest, from an enemy on a hill* 35 *feet in height, and* 300 *yards in front of the crest. Calculate the necessary command.*

N.B.—It must be understood that the necessary cover for the defenders, in addition to the height of $5\frac{1}{2}$ feet, would be obtained by lowering the ground behind the parapet.

In this case the plane of defilade rises in the whole distance (300 + 18) a height of $35' + 4\frac{1}{2}' - 5\frac{1}{2}' = 34'$; its rise in the distance to be protected (18 yards) must then be found, and added to $5\frac{1}{2}'$ (cover required), to obtain the required command.

Yds. Yds. Ft. Ft.
318 : 18 : : 34 : 2 nearly { the rise of the plane of defilade in the distance of 18 yards.

∴ Command of parapet $= 5\frac{1}{2}' + 2' = 7\frac{1}{2}'$.

Example 3.—*A parapet on level ground, having a command of* $8\frac{1}{2}$ *feet, is exposed to reverse fire from a hill* 500 *yards behind its crest, and* 58 *feet in height. What must be the height of a parados* 12 *yards behind the crest of the parapet, to cover the defenders of the banquette to a height of* 7 *feet?*

In this case the banquette of the parapet is $8\frac{1}{2}' - 4\frac{1}{2}' = 4'$ in height; the plane of defilade of the parados must therefore pass $7' + 4'$ or $11'$ above the ground at the position of the (crest of the) parapet. The rise of the plane of defilade in the whole distance (500 yards) is $58' + 4\frac{1}{2}' - 11' = 51\frac{1}{2}'$; its rise in the distance to be protected (12 yards) must then be found, and added to $11'$ (height of plane of defilade at parapet), to obtain the required height for the parados.

Yds. Yds. Ft. Ft.
500 : 12 : : 51·5 : 1·236 { the rise of the plane of defilade in the distance of 12 yards.

∴ Height of parados $= 11' + 1{\cdot}236' = 12{\cdot}236'$ or $12\frac{1}{4}'$ nearly.

Example 4.—*A parapet on level ground, with a command of* $7\frac{1}{2}'$, *is commanded in its front by a hill* 280 *yards distant and* 59 *feet in height. Required the depth to which the ground must be lowered at a point* 15 *yards behind the crest of the parapet to obtain* 7 *feet of cover.*

In this case the cover afforded by the parapet (height of its plane of defilade) at the given point must first be determined, and then subtracted from the required cover (7 feet) to obtain the depth to lower the ground.

The rise of the plane of defilade in the distance from the parapet to the hill (280 yards) is $59' + 4\frac{1}{2}' - 7\frac{1}{2}' = 56'$; its fall in the distance of 15 yards must then be found, and *subtracted* from $7\frac{1}{2}'$ (command of parapet), to obtain the cover above ground at the given point.

Yds. Yds. Ft. Ft.
280 : 15 : : 56 : 3 { the fall of the plane of defilade between the parapet and given point.

∴ $7\frac{1}{2}' - 3' = 4\frac{1}{2}'$, the cover afforded by parapet at given point.

and $7' - 4\frac{1}{2}' = 2\frac{1}{2}'$ { the required depth to sink the ground at the given point.

CHAPTER VII.

EXECUTION OF FIELD WORKS.

Determination of outline of works and of the profile suitable for the parapets, also for the ditch. Method of tracing works before their construction is commenced. Use of profiles, direct and oblique: how to erect them. Distribution of an ordinary working party. Employment of one or more rows of diggers; the time required for a work; importance of proper drainage; usual method followed.

Description of the Service FIELD LEVEL.

ADDENDA.—*Estimates of time required for the construction of ordinary field works.*

312. In the actual construction of Field Works the following operations have to be performed:—

(1.) The *outline of the work* has to be determined with reference to its intended object, the fire required from it, the available garrison, and the shape of the ground which it is to occupy: each of these conditions affects either the shape of a work or its size.

(2.) The *profile of each separate line of parapet* can then be determined.

The *Command* depends not only on the cover required, but on the necessity for sweeping, by the fire from the parapet, the slopes of ground in front; and thus the outline and the profile are to a considerable extent mutually dependent.

The *thickness of parapet* depends on the exposure to fire. The front faces of a work—*i.e.*, those facing to thef ront of a position—will require the thickest parapets, on account of their exposure to direct cannonade, and at the same time their parapets will usually be the highest ones of the work, in order to cover the interior of the work from fire.

The lateral and rear faces may generally be constructed with less command and also thinner parapets than the front faces.

(3.) The shape of the work and the profile of its parapets having been determined, the dimensions of the ditches for the several parapets (also their *trenches*, if any are used) are able to be laid down.

(4.) The work can then be traced on the ground in readiness for the working party.

(5.) The execution of the work can be commenced.

313. The following operations are necessary in tracing and profiling an ordinary field work, and are usually undertaken in the order stated. (See Fig. 284, Plate XXX.).

(1.) Fix the angles A, B, C, D, &c., of the crest lines (which are the magistral lines) of the work by stout pickets, flags, &c.

The imaginary lines which join these points give the plans of the crest lines, which, however, do not require to be actually marked on the ground.

(2.) To each magistral line (as A B, B C, &c.) two perpendiculars should be traced, usually through points 6 or 8 yards from the ends; and along each of these perpendiculars pickets should be driven in, to mark the base of each slope of the parapet, and also the cutting lines of the excavations.

By this arrangement two points will be fixed in each line of the parapet, &c., and any line necessary to be marked on the ground is therefore at once obtained by joining these points.

(3.) At each angle of the work, whether salient or re-entering, the points which mark the intersections of the corresponding lines of the parapets on either side should then be fixed by pickets.

(4.) *Direct profiles* at the perpendiculars, and *oblique profiles* at the angles, are then erected.

(5.) The cutting lines of the excavations are then *spitlocked*, *i.e.*, marked with a small groove cut with a pickaxe or spade.

The bounding lines of the parapet (*i.e.*, foot of the exterior slope and foot of slope of banquette) may be marked, either by spitlocking or by tapes, &c., in order to show clearly the space between them which is to be covered with the earth for the parapet.

314. Fig. 284, Plate XXX., is a plan of three lines of parapet forming a re-entering angle (A, B, C) and a salient angle (B, C, D). The command of the parapet is $7\frac{1}{2}'$, thickness of ditto 12′. A ditch 10′ in depth and 4′ broad at bottom, with escarp $\frac{1}{4}$ and counterscarp $\frac{2}{1}$, is to be made. The work is shown as traced according to the foregoing description in readiness for the working party. The large dots on the plan indicate points necessary to be fixed by pickets. The details of the excavation of the ditch for *four-hour* reliefs are given in Fig. 285, Plate XXX.

315. *Setting up Profiles.*—To erect a profile with parapets of low command (6′ or under), erect an upright ($3'' \times \frac{3}{4}''$) at the position of the crest, or *firing line* (Fig. 288, Plate XXXI.), making it of the proper height; erect others at the positions of the exterior crest and the front and rear of the banquette; and at the foot of the exterior slope and of the slope of the banquette drive in stout battens. The actual slopes of the parapet are shown by other battens being nailed from one to another of the uprights, at the proper heights, with their upper edges flush with the surface of the several slopes. When an interior slope has to be revetted, the profile of that slope is fixed with its *under edge* in the slope.

Lines may be used to connect the uprights, instead of battens.

316. For parapets of higher command it is better (as in Fig. 289, Plate XXXI.) to drive square-headed pickets at the points under the intersections of the several slopes, their tops projecting 2 or 3 feet above the ground.

Battens of the exact height of the different points are then laid on the ground, touching their respective pickets, and at right angles to the section, and their tops are connected by other battens to represent the different slopes; the whole is then raised, and fixed to the pickets by nails, the profile being supported, if required, by side stays.

317. In erecting the oblique profiles the heights are, of course, the same as for the corresponding parts of the direct profiles.

In long lines of parapets, two direct profiles to each line will not suffice; others should be placed at convenient positions.

When material for profiles is scarce, the uprights only may be used, with small cross pieces to mark the angular points of the profile. Although not indicating the slope of the parapets so clearly as the regular profiles, this method has the advantage of not impeding the movements of the workmen on the parapet, and is less affected by wind.

Wood profiles are usually left where placed, as they facilitate repairs to the parapets.

318. *Distribution of Workmen.*—In throwing up earthworks, whether for field or siege service, it is almost always desired to execute them in the shortest possible time. To this end the following points have to be attended to:—

(1.) That the men be distributed as thickly as is possible, without interfering with one another.

(2.) That the maximum of work be got out of them.

With regard to the first point, diggers should not, as a rule, be closer to one another in commencing work than 5 feet, or 2 ordinary paces. This is regarded now as the normal interval for diggers, and it is convenient. If closer, the men interfere with one another.

Two rows of diggers in one excavation are only employed when they can work back to back, and throw the earth outwards; as, for instance, in a ditch where one row of diggers on the escarp side would throw earth on to the parapet, and a second row of diggers on the counterscarp side would throw earth to form a glacis. Thus, in excavating for a field redoubt having a rear trench, and a glacis about 2 feet high (as in Plate XXIV., Figs. 227, 228), there could be, *at the outset*, three rows of diggers, viz., two in the ditch throwing respectively on to the parapet and glacis, and one in the rear trench throwing on to the parapet; and this would be a good arrangement for obtaining the maximum of ditch as an obstacle in a given time, as well as a maximum of earth for the parapet.

Further, when it is required that the earth excavated be deposited more than 12 feet from where it is obtained, there must be a row of *shovellers*, to pass it on. The shovellers are usually from one-half to two-thirds of the number of diggers.

Next, in order that the maximum of work may be obtained from the men during the time for which they are employed, it may be assumed that in moderately easy soil (gravel, loose earth, &c.) a soldier untrained to the use of the pick and shovel can, in *four hours' actual work*, excavate 100 cubic feet, or very nearly one cubic yard per hour, throwing the earth a horizontal distance of 12 feet, and lifting it out of a trench having a maximum depth of 4 feet; and that the same man if kept at work for 6 hours would not do very much more, as his energies would be pretty well expended after the first 4 hours' work. It is for this reason that 4-hour reliefs, with tasks of about 100 feet, are recommended for all hasty field defences. See the tasks noted for the 3 profiles in Plate XXX.

After some practice, however, it may be assumed that the same man will excavate, under similar circumstances, 1 cubic yard per hour for 6 hours.

319. The working party for the commencement of an ordinary field parapet and ditch, without trench (as shown in Fig. 285, Plate XXX.), will be composed of one row of diggers in the ditch, and one row of shovellers to pass on the earth to form the parapet.

The diggers, each provided with a pickaxe and shovel, are posted along the escarp cutting line, at 5′ intervals, and facing the parapet. Each digger marks with his pickaxe the left point of his 5′ portion.

The shovellers, each provided with a shovel only, are posted in a line parallel to that of the diggers and 12 feet from them. In Fig. 285, 2 shovellers are allotted for every 3 diggers; this is a fair proportion for ordinary cases. As the earth is passed up by the diggers and thrown by them 12 feet towards the parapet, the shovellers pass it on and spread it over the ground to be covered by the parapet.

320. The distance to which the earth is thrown should be equalized as much as possible: at the commencement of work, when the diggers are close to the escarp, the earth should be passed to the banquette slope and the parapet at that part formed; but when the diggers are working near the counterscarp the earth would be passed so as to form the front portion of the parapet. By this means the earth of any one layer of the ditch will be used to form a corresponding layer of the parapet, as far as is practicable.

If the soil is known to be difficult, so as to cause a less quantity of earth to be supplied by the diggers, the shovellers may be reduced in number to one-half of the diggers. In any case their number ought to be only sufficient to pass on the earth and spread it properly, as fast as it is supplied by the diggers.

The proportion of 2 shovellers to 3 diggers, with the latter at 5′ interval, as shown in Plate XXX., gives an average of 1 workman per yard lineal of work, as it allots 5 men (3 diggers and 2 shovellers) to every 5 yards of work.

321. Where trenches are used, as in Figs. 281, 282, Plate XXX., additional rows of diggers can be employed; and for this reason the necessary earth is quickly supplied and the works are rapidly completed. This advantage is still further increased when the command of the parapet is reduced, owing to the cover afforded by the trench allowing such to be done. In each of the two figures referred to the cover given is 9′, consisting of a parapet 6′ in height and a trench 3′ iu depth.

322. When the workmen are posted in their places, their respective duties should be explained to them: each digger should mark clearly with his pickaxe the lines bounding the space allotted for his task.

The order to "commence work" being given, the diggers commence digging:

on the *left* of their respective tasks, and work towards the right. They should be made, at the commencement of work, to throw the earth 12 feet towards the line of shovellers.

The shovellers should pass on the earth as the diggers supply it, without allowing it to accumulate in heaps.

In digging ditches and trenches having sloping sides it is a rule to commence the tasks by excavations having vertical sides, the slopes being finished last. By this means the mass of the excavation is done without loss of time. The ditch is usually dug in successive layers of 3 feet in depth: the actual depth may be varied to suit particular cases. In Figs. 283—285 the ditch is 10′ deep, and is dug by successive layers of 3, 3, and 4 feet in depth.

When making the excavation deeper than 6 feet, a step must be left, on to which the diggers throw the earth, which is lifted thence into the parapet by shovellers. See the ditches of Figs. 281, 285 as illustrative. Finally this step is cut away and the slopes completed.

323. The tasks of the several reliefs of diggers for the works shown in Plate XXX. are all calculated for 4-hour reliefs, the diggers in each case being at 5′ intervals. The three works therein shown will be able to be executed in the following number of *actual working hours, by relays of men* :—

Fig. 282,	with a ditch	32	square feet in profile, in	6	hours.
Fig. 281	,, ,,	58	,, ,,	16	,,
Figs. 283-4-5	,, ,,	115	,, ,,	28	,,

It will be observed that while the tasks of the first reliefs of diggers are about 100 cubic feet each, those of succeeding reliefs are made less, owing to the greater difficulty of throwing the earth. The problem attempted to be solved is to make the tasks of equal difficulty.

324. The time required to throw up a work may be calculated approximately. With a given distribution of men, the time depends on the dimensions of the profile and on the nature of the soil. The trace of the work does not materially influence the time required for its construction, provided it be commenced throughout at the same time.

If the workmen are properly proportioned, it will only be requisite to estimate the time required to excavate the ditch, as the parapet ought to be built as fast as the ditch is dug.

The time required to dig a ditch with a row of diggers at equal intervals will evidently be that which is required for one digger to excavate his portion (usually 5′) of the ditch.

As before stated, the quantity of excavation to be expected from a digger is about 1 cubic yard per hour for a 4-hours' task when untrained, or for a 6-hours' task when some practice has been obtained. This refers to soil of ordinary nature. In exceptionally light soils more work can be obtained, and in very difficult soils much less must be reckoned on. The nature of the soil frequently varies very much in the same excavation: all of which tends to make precise estimates of time impossible, as the exact data cannot be laid down.

325. On the above suppositions, the number of actual "*working hours*" required to throw up a field work of known profile will be thus found:—

Estimate in cubic yards the contents of the length of ditch (usually 5′) occupied by each digger.

In ordinary soil, with 4-hour reliefs, the number of cubic yards will give the time in hours.

326. In throwing up works there is always a superabundance of earth at salient angles (which is very useful for gun-banks, if such are made), and a deficiency at the re-entering angles, as will be evident from Fig. 286, Plate XXX., where the shaded part of the ditch at each angle supplies earth for the shaded part of the parapet.

This is an inconvenience which may be partially remedied by making the workmen throw the earth obliquely towards the re-entering angles, and, if necessary, the ditch near the re-entering angles may be widened.

With trenches as well as ditches, the inconvenience does not exist, at least to such an extent.

When, notwithstanding the precautions taken, there is still a superfluity of earth at the salients, it must be got rid of by forming a small glacis in front.

327. The importance of draining a work is very great; and steps should be taken to effect this before beginning the work, as much greater difficulty will be experienced afterwards if no provision is made at first.*

Should the ground fall to the rear of an open work, the chief operations necessary would be to form open gutters or drains to lead off the water in the required direction to the rear.

But should the ground fall towards the salients, the water must be led to the front, under the parapet, into the ditch.

To effect this, drains should be cut through the ground to be covered by the parapet, and filled up with fascines and large stones, as in Fig. 287, before the parapet is built over them, so as to let water soak through them.

All enclosed works should be drained in this manner. If bricks, &c., are available, regular covered drains may be made. Where the water is led into the ditch, precautions should be taken, to prevent its injuring the slope of the escarp, by prolonging the drain beyond the escarp, and by revetting the latter, and a portion of the bottom of the ditch, with stones, &c.

328. *Description of the Service Field Level.*—The Field Level, Plate XXXI., is used for setting off angles on the ground, and also for measuring slopes.

It consists of 3 pieces of wood, marked A, B, and C, which can be put together in various ways, and by means of a plummet made to exhibit a number of angles and slopes, according to the position in which it is held: the instrument is graduated by experiment, and forms an article of Engineer equipment.

Fig. 290 shows the level folded up, when not in use.

Fig. 291 shows the level arranged for measuring gentle slopes—*i.e.*, from the horizontal up to slopes of $\frac{1}{1}$.

Fig. 292 shows the level set for steep slopes. In the figure a slope of $\frac{4}{1}$ is being tested.

In Fig. 293 the level is arranged for setting off perpendiculars, and in Fig. 294 for laying off on the ground horizontal angles.

It is a most useful instrument for field purposes, but its use is best learned by actual handling in practical work.

329. ADDENDA TO CHAPTER VII.—ESTIMATES OF TIME REQUIRED TO CONSTRUCT PARAPETS.

EXAMPLE 1.—*Calculate the time,* in working hours, *required to construct a line of parapet and ditch, the latter having an area in profile of* 120 *square feet.*

Diggers at 5′ *intervals: relays of workmen, so as to permit* 1 *cubic yard per hour per digger being obtained.*

Area of ditch = 120 square feet.

$120 \times 5 = 600$ cubic feet
$= 22\frac{1}{4}$ cubic yards } The amount of earth for the portion of ditch (5′) occupied by each digger.

In this case the number of cubic yards will be the time in *working hours,* viz., $22\frac{1}{4}$.

EXAMPLE 2.—*Calculate the time required to construct a line of work having a ditch with area* 24 *square feet, and a trench with area* 18 *square feet.*

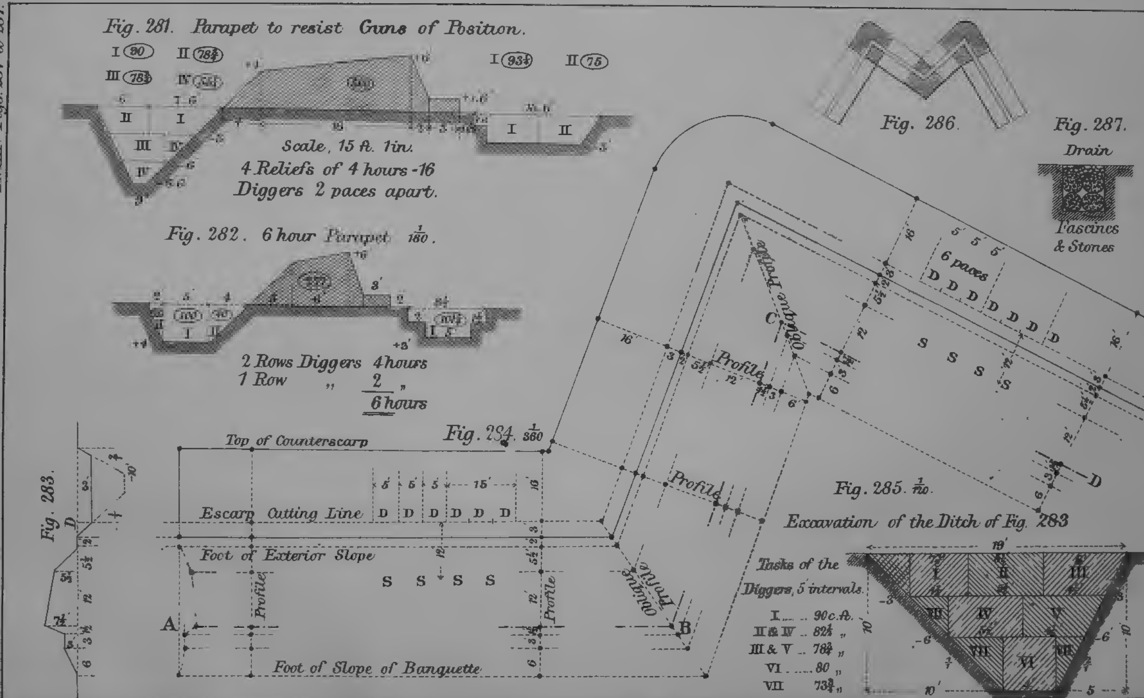
In this case it is only necessary to calculate for the ditch, that being the larger excavation; the trench can of course be done in less time.

$24 \times 5 = 120$ cubic feet
$= 4\frac{4}{9}$,, yards } amount of earth in the ditch per digger.

The time will therefore be $4\frac{4}{9}$ (say $4\frac{1}{2}$) working hours.

* Sir John Jones, in his "Memoranda on the Lincs of Torres Vedras," vol. iii. p. 78, says:—"To ensure an efficient system of drainage should always be a priucipal consideration

Pl. XIX. Figs. 281 to 287.



PROFILING.

PROFILE NOT EXCEEDING 6' IN HEIGHT.

Fig. 288

Fig. 289.

FOR HIGH PROFILES

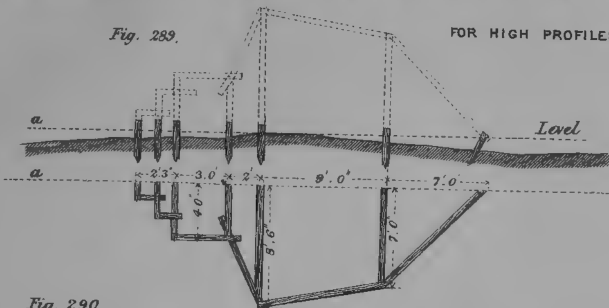
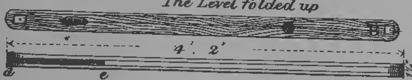


Fig. 290.

The Level folded up



FIELD LEVEL

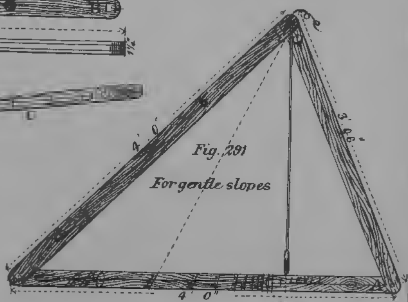


Fig. 291

For gentle slopes

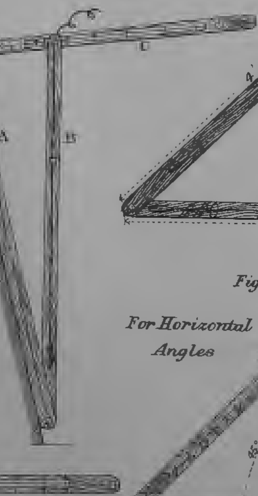


Fig. 292

For Steep Slopes

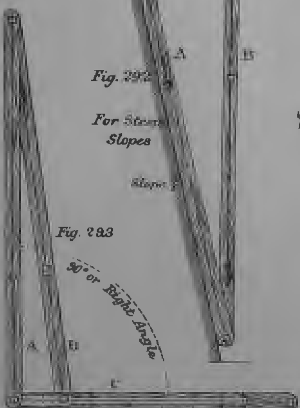
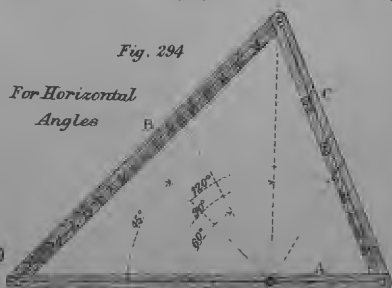


Fig. 293

For Right Angles

Fig. 294

For Horizontal Angles



EXAMPLE 3.—*A line of parapet, with ditch area 140 square feet, and glacis area 14 square feet, is to be commenced by two lines of diggers at $4\frac{1}{2}'$ intervals in the ditch: those on the escarp side to form the parapet; those on the counterscarp side to form the glacis, and afterwards to become an extra line of shovellers.*

What time will be required for the work, the soil being such that 20 cubic feet per hour is to be supplied by each digger.

Area of ditch = 140 square feet.
Deduct area of glacis = 14 ,, ,,

Area of portion of ditch to supply earth for parapet . = 126 ,, ,,

$\therefore 126 \times 4\frac{1}{2} = 567$ cubic feet, { the amount of earth in the portion of ditch ($4\frac{1}{2}'$) occupied by each digger, who is to excavate 20 cubic feet per hour; therefore,

$\frac{567}{20} = 28\frac{7}{20}$ hours, the time required.

CHAPTER VIII.

COMBINATIONS OF WORKS, BRIDGE HEADS, ETC.

LINES OF INTRENCHMENT, *various kinds of.* SINGLE LINE OF WORKS: *dispositions for, under varying circumstances.* DOUBLE LINE OF WORKS, *when used, how arranged.* ADVANCED WORKS, *when necessary.* CONTINUOUS LINES, *when resorted to.* BRIDGE HEADS, *Double and Single. Positions suitable for each. Single Bridge Heads, examples of. Method of arrangement. Conditions to be fulfilled. Mode of abandoning in presence of an enemy.*
ACTION OF STREAMS *in winding rivers: formation of fords, &c.*

330. When several works are combined for the defence of an extended position they are called "*Lines*," and, as regards their nature, are divided into two groups, viz., *Continuous Lines*, so named when they consist of a continuous line of defensive works; and *Lines with intervals*, or *Broken Lines*, when they consist of separate and distinct works, which usually mutually defend one another, but not necessarily so.

331. As regards their object, they form an *Intrenched Camp* when they enclose a space, usually resting on a fortress, in which an army may receive shelter and remain on the defensive until reinforced or reorganized. When they are thrown up by a besieging army to resist the sorties of the garrison they are *Lines of Investment* (formerly *Lines of Contravallation*); and when they are intended for the sole purpose of allowing a defensive force to give battle to an enemy they become "Intrenched Positions."

332. In all these cases the fortification of the positions taken up, whether in a straight, concave, or convex line, is applied in the same way, viz., in providing a chain of tactical pivots, varying in their strength and distance apart according to the passive or active character of the defence, and to the nature of the ground.

333. *Single Line of Works.*—The distance of works from one another for effective support by fire is as follows:—Fig. 295, Plate XXXII.: For reciprocal defence by musketry, 350 to 500 yards (say a quarter of a mile) between the capitals; with guns firing shrapnel, 850 to 1,800 or 2,000 yards ($\frac{1}{2}$ mile to 1 mile, say) between the capitals.

For defence of the intervals only, those distances may be doubled. For the advance of a deployed battalion, regiment of cavalry, or battery of artillery, 300

with an officer on commencing a work. Some redoubts deeply excavated with a view to screen the defenders, particularly Nos. 101 and 102 at Oeyras, from neglect of this precaution literally filled with water, in September, 1810, and the labour of forming drains to keep their interior dry was little less than that of constructing the redoubts."

yards clear space is sufficient. For the advance of a brigade, 800 yards at least will be necessary.

On a straight line, Fig. 295, Plate XXXII., the capitals of the works should be perpendicular to the line; the works themselves lunettes with blunt salients.

The works are, as it were, the bastions of the line; the spaces between the works are the curtains, either open or closed.

On a convex line, Fig. 296, Plate XXXII., the capitals of the works would naturally radiate from the centre. The works "lunettes" with the salients sharper as the curve is greater; the faces should be directed on to the inner end of the flanks of the collateral works.

This arrangement is applicable to the defence of a central point within the line (*e.g.*, *bridge heads*).

On a concave line, Fig. 297, Plate XXXII., the capitals of the works would naturally converge towards a central point in front.

The works would be lunettes, or, as shown in Fig. 297, the front of each work would usually be a straight parapet.

334. In each of the three cases above referred to the faces must be arranged so as to sweep the foreground by their fire, while the flanks should be directed so as to sweep the intervals and cross their fire close in front of the neighbouring works.

The gorges of the works, if they are enclosed, should be either straight, if such be not inconvenient; or may be broken slightly outwards, as in Fig. 198, Plate XXI., either with the object of gaining sufficient interior space, or of enabling a gorge tambour (or other flanking work) to assist in the defence of the intervals between the works.

Intermediate works, as *a*, Fig. 196, Plate XXI., are necessary when the distance between the main works is unavoidably greater than the maximum distances before mentioned, or when the ground between them is not well commanded by their fire.

They are usually retired behind the front line not more than a quarter (a half is the extreme limit) of the distance between the works, to ensure good fire effect. Their salients, therefore, are not smaller than 120°. Their form, that of "*Flèches*," or "*Blunted Redans*." Their gorges would usually be open. Their profile may be of a slight character.

They are good positions for Artillery.

335. *Double Line of Works.*—When the defence is to be a very obstinate one, provision must be made in case of the penetration of the first line by a second line of works, forming the rallying position, to be at least 600 yards behind the first line.

The second line supports the first line with artillery, and necessitates a fresh infantry attack on the part of the enemy. The character of the works may be closed redoubts; intermediate works (if any) open or half closed.

The distance named gives ample room for the movements of brigades.

336. *Advanced Works* are frequently necessary to observe ground unseen from the main line, or which may be especially favourable to the effects of the defenders' fire. Advanced works should be within effective rifle range of the main line, if possible under 600 yards; for support by artillery only within 1,500 yards.

The works (of two or more sides, according to their prominence), not being required to make a serious resistance, may be usually "*open*," and need not have front ditches; shelter trenches are generally sufficient.

If necessarily beyond effective rifle range, they must be "*half closed*," as *f*, Fig. 196, Plate XXI., and the work or works then partake of the character of a first line.

The fire of the "supporting point" may, if necessary, be increased by placing flêches on the sides (*e*, Fig. 196, Plate XXI.). These are flanked by the works, and must themselves be protected by obstacles from flank attack.

WORKS IN COMBINATION.

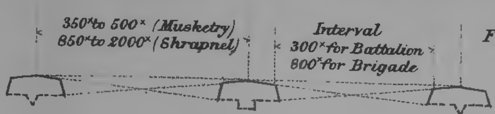


Fig. 295

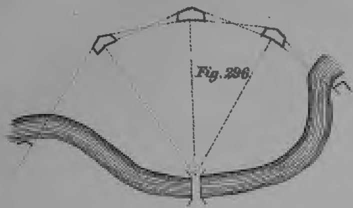


Fig. 296

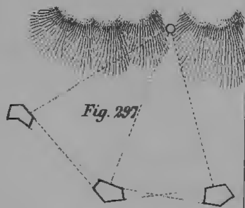


Fig. 297

Fig 298

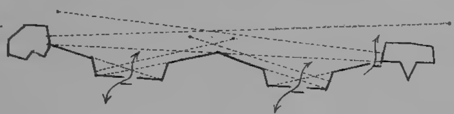


Fig. 299

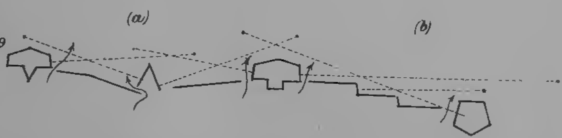
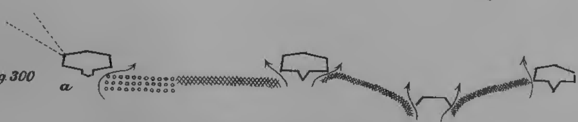


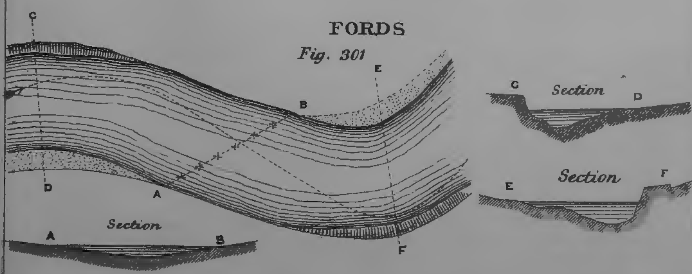
Fig. 300



Intervals closed with Obstacles

FORDS

Fig. 301



337. *Continuous Lines.*—When the nature of the ground, or the condition of the defenders, renders it undesirable to make counter-attacks, the front of a position may be wholly covered by defensive works of strong profile.

In such a case, detached works are designed as before, as the supporting points of the line, and the intervals between them closed by lines of parapet or by obstacles or by both (Figs. 298—300, Plate XXXII.).

The distance of the supporting points asunder, not being intended for movements of troops, may be reduced for the sake of powerful support by fire.

The connecting lines should be as simple as possible in trace, mostly straight; and of as strong a profile as time and means will allow; but if the intervals to be closed are necessarily great, the connecting lines may be traced so as to supplement the flanking defence of the supporting points.

In Fig. 298 the interval is closed by a couple of bastioned fronts joined together.

In Fig. 299 (*a*) a central redan gives the additional flanking fire.

In Fig. 299 (*b*) the connecting line is an *indented line*: this form is suited for a retiring line, as it preserves the directness of the fire; the flanks must be protected from enfilade by heightening the parapet at each shoulder.

Fig. 300 shows the intervals closed with obstacles only.

Narrow openings for ordinary communications must be left in the connecting lines.

338. Bridge Heads, *as an example of the combination of works.*—A *bridge head* is a work or series of works constructed for the purpose of protecting the communication across a river by means of one or more bridges.

When works are required for the defence of both ends of the bridges, or, in other words, when the attack may come from either side of the river, the arrangement of works is termed a *Double Bridge Head.* Such an arrangement becomes necessary when a force operating on both sides of a river may require to concentrate on *either* side for purposes of attack; or may be driven by an assailant from either side to the other.

When works are required to protect only one end (the head) of the bridges, they form a *Single Bridge Head*: this is the case when a force operating on one side of a river seeks to protect its retreat to the other.

Fortresses which occupy both sides of a river form Double Bridge Heads of a permanent nature, and give to the army possessing them the great advantage of being able to operate on either bank of the river, or on both banks at the same time.

339. A Double Bridge Head should be placed (if a choice of position exists) either at a straight part of a river, or else at the confluence of two streams. In the former position the ground is equally defensible from either bank, while in the latter the ground to be protected is divided into three zones, on either side of which, if attacked, the defenders can concentrate their principal forces, merely guarding the remainder.

340. The best position, as *regards facility of defence* of the actual point of passage, for a *Single Bridge Head*, is a re-entering bend—*i.e.*, one concave towards the enemy, because in that position the near bank (which is usually higher than the further one), being salient on each side of the bridge head, envelopes it to a considerable extent, so that batteries and other works on that bank can flank the bridge head with great effect, provided the river be not very broad. The bridge is also well screened from view, and the ground in front being comparatively limited in extent, can be submitted thoroughly to the fire of the various defensive works. It will also be found in a re-entering bend that the defensive works can be traced with great security from enfilade fire. All these advantages arise from the re-entering position, which is naturally strong, even without defensive works, and is therefore peculiarly suited for *forcing the passage* of a river.

A bridge is a narrow defile, and to pass it in presence of an enemy, one important consideration is to check the hostile force sufficiently far off to afford time for the passage of the troops.

The two villages would then be abandoned; the defenders of that on the left would retreat by the bridge A, and blow it up, if not already done. Otherwise they would retreat by the other bridges.

The defenders of the intermediate works on the central hill would next fall back and cross the bridges.

Lastly, the defenders of the works covering the heads of the two bridges would be withdrawn, completing the abandonment of the further side of the river, in which case the two bridges would most probably be destroyed, so as to deny their use to the enemy.

345. *Action of streams in winding rivers; formation of fords, &c.*

While re-entering bends of rivers form the best defensive position for a bridge, for the reasons above stated, the action of the water in a winding river frequently unfits such positions for the establishment of a military bridge.

A current running in the direction of the arrow in Fig. 301 will continue in its straight course until it impinges on the curved bank at C, which will cause it to deflect to the right: it will then take an oblique direction across the river (as shown by the dotted line), and at the next curve of the river it will impinge on the bank at F′, and be again deflected obliquely across to the other bank. This change of direction from side to side will continue as long as the course of the stream is winding. This is shown in Fig. 301, where the dotted line represents the general direction of the current: thus the stream is always running in the winding parts of a river obliquely to its banks; and this oblique direction causes the stream to take effect on the sides of the boats, or other floating bodies forming the piers of a military bridge, instead of on their bows. When the current is very rapid, from floods or other causes, this oblique action of the stream may exert such a strain on the piers as to carry away the bridge.

Another reason why the curved parts of rivers may be bad positions for establishing bridges is, that at those parts the depth of water, and also the nature of the bottom, are very variable.

In Fig. 301 the stream rubs against the banks at the concave parts C and F′; and as a result, the velocity of the stream at those parts is increased, the banks are being continually worn away, and the soil carried down stream to form shoals elsewhere. The banks of the stream at C and F′ will be therefore very steep, and the depth of water at the same points will be probably the greatest. On the other hand, the converse effect happens at D and E′, for there the velocity of the stream is very slight, perhaps *nil;* sometimes, as in a very sudden bend, there may be even a backwater at D and E′: this slackening of the current at these points leads to the deposit there of the matter brought down by the stream, and shoals are thus formed, while the opposite banks are being worn away.

With reference to the formation of shoals at those parts where a rapid current is slackened from any cause, the following table gives the greatest velocity which each of the various substances named can resist, without being moved:—

	Velocity of water at the bottom necessary to produce movement.	
For fine sand	6 inches per second.	
„ coarse angular round do.	8 „ „	
„ gravel { fine, size of a grain of aniseed.	4 „ „	
„ gravel { mean, size of a pea	7 „ „	
„ gravel { coarse, size of a bean. ...	12 „ „	
„ pebbles, an inch in diameter	24 „ „	ordinarily swift.
„ angular stones, size of an egg ...	36 „ „	rapid.
„ „ „ „ ...	5′ to 8′ „	very rapid.

This unequal action of the current is illustrated by the sections at C D and E F, Fig. 301, which show deep water with steep banks at one side (C and F), and shallow water with shelving banks at the opposite side (D and E).

A sudden fall of the stream at such a position might be very injurious to a floating bridge, for one part might be left aground, while the other, dropping with the fall of the water, would be torn away from it.

When a bridge is established across a river, special precautions must be taken to prevent its being injured by floating bodies carried down by the current. Boats stationed on the up stream side of the bridge should watch for such bodies, and should either tow them on shore before reaching the bridge, or, in the event of their being unable to effect this, should guide them to any opening that may be made in the bridge to allow them to pass through.—Art. 542. Cuts in bridges.

346. From the foregoing observations it will be apparent that in a winding river fords may frequently be found running *obliquely* across it from one *convex part to another*,* as shown in Fig. 301 by the line + + + + ; but, in general, fords are to be looked for at enlargements of a river, where its course is straight.

A ford to be passable should not be more than 4 feet deep for cavalry, 3 feet for infantry, and 2′ 4″ for artillery.

In rivers, the bottom of which is moving sand or fine gravel, the fords are dangerous and deceitful; because, if large bodies of troops have to pass and the current is strong, the sand stirred up by the operation will be carried away, and the ford will probably become impassable for the rear of the line of march.

The best precaution for passing a ford is to drive two rows of pickets at small distances apart, to show between them the line of the ford; strong ropes should be passed along each row, taking a turn round each picket.

A good method of reconnoitring a ford is to descend the river in a boat with a sounding line hung over the stern, adjusted to the requisite ordinary depth of 3 feet. Conducting the boat in the direction in which, from the principles already laid down, fords are most likely to be found, the sounding line will indicate when it touches the bottom; and the direction of the ford, its width, the nature of bottom, &c., can be ascertained and laid down.

CHAPTER IX.

DEFENCE AND ATTACK OF POSTS, ETC.

DEFENCE OF A HOUSE: *conditions to be fulfilled; garrisons requisite; operations to be performed; tambours, machicoulis galleries, loopholes, obstacles, &c.* DEFENCE OF A VILLAGE: *variety of conditions; when undertaken; operations to be performed; Garrison requisite, its distribution; Barricades.* DEFENCE OF WOODS: *principles to be followed; operations to be performed; Garrison, how distributed.* ATTACK ON A HOUSE: *variety of cases, by day or by night, with or without artillery. Defending a house against assault.* ATTACK ON FIELD WORKS, STORMING: *the four periods of operation described; method of passing obstructions; mode of holding captured works.* BY SURPRISE *described.* BY CANNONADE. DEFENCE OF FIELD WORKS AGAINST SURPRISE: *steps necessary.* AGAINST STORMING: *four periods of the defence.* HASTY DEMOLITIONS *with gun-cotton and gunpowder: of walls, houses, gates, bridges of wood, iron, or masonry.* RAILWAYS and TELEGRAPHS, *how to disable and destroy.*

ADDENDA: *Examples of fortified posts in war of* 1870-1. DATA *for Estimates of varieties of works in defence of Posts, &c.*

347. DEFENCE OF HOUSES.—Buildings may be used for defence under many different circumstances, either singly or in combination with others.

Some of the principal cases in which it may be desirable so to use them are the following:—

1. As tactical points in the battle field, either as advanced posts, as supporting points in the line or on its flank, or as rallying points to cover a retreat.

* In Sir Howard Douglas' "Military Bridges," p. 21: "The author has frequently found rivers fordable in this manner, which could not be crossed perpendicularly at any point. The Spanish army, with which the author served, forded the Esla in the campaign of 1812, without loss or difficulty, by taking advantage of this circumstance; and in the same manner he forded the Duero near Lamora, and several other formidable rivers."

2. As reduits to a more extensive locality, rendered defensible, such as a village or a wood.

3. As isolated posts on the lines of communication of an army.

348. Houses are suitable for defence if solidly built, large enough to hold at least half a company, well situated for the object in view, and where from them can be seen all the ground in the vicinity within musketry range.

If liable to attack by field artillery, they are defensible when unusually massive and built of brick or soft stone (in preference to hard stone which splinters), and with low or flat roofs, or when the features of the ground, or woods, or houses screen them from the fire of the enemy's artillery, unless the guns be brought within range of the rifles of the defenders. Hence it will be observed that *buildings are better suited for defence when in hollows than when on high ground,* because they are sheltered from distant artillery fire; the height of the walls defilades the defenders from the fire of infantry on the adjoining hills, while the fire of the defenders is fully effective on the enemy's infantry attempting to pass the counter-sloping glacis to storm the building, or on his artillery when brought up close to breach the walls.

Houses which have parts flanking one another, or which have porches and bay windows, are good for defence.

A substantial house can be quickly converted into a defensible post, giving absolute security from cavalry, and very great advantage in a contest with infantry; but unless the walls be very massive, they can readily be breached by field artillery, and the bursting of shells inside the building, combined with the fires probably kindled by them, will make the prolonged defence of an ordinary building, subjected to a combined attack of infantry and artillery, almost hopeless. No banking up of earth against the lower parts of the walls will have any effect in preventing shells from penetrating the upper portions and setting fire to the building.

349. The *Garrison of a House* may be estimated at two men to each opening to be defended (door, window, or loophole), at least on the ground floor, to one man to each loophole on other floors, with a reserve of $\frac{1}{4}$.

A strong building may be defended by even a smaller garrison than this, but the actual garrison will depend in some measure on the importance of the post; and it should always, if possible, be a tactical unit.

350. *To fortify a building,* the following are the successive steps which should generally be taken. (See Plate XXXIV.)

1st. For a very hasty defence: Time 1 to 3 hours.*

(*a*) *Remove the inhabitants,* and all easily *combustible materials, and provide water.*

(*b*) *Barricade the doors and accessible windows* so as to resist ingress and musketry fire. Inaccessible windows should at least be masked, so as to hide the defenders, and the glass broken out; one door with a movable barricade, or a window with a ladder, should be reserved for escape.

(*c*) *Make loopholes.* These should be left open in barricades. They may be made with the axe in doors and window shutters; with the pickaxe or crowbar in thin walls; or by removing tiles at the eaves of the roof.

(*d*) *Clear away cover* in the vicinity as far as time and means allow. In doing this, obstacles should be created when possible.

351. 2nd. For the careful preparation of a building for defence. Time, 24 to 48 hours.

(*a*) *Make a rough survey of the building and its vicinity,* and determine on the plan of defence, particularly what outbuildings or parts of the main building are to be destroyed; what is to be the extent of the defensible enceinte; what

* Where time and means are at a minimum, as in the case of buildings stormed during a battle, and to be held as tactical points to secnre the ground won, it may only be possible to make loopholes and to barricade the doors. Loopholes even may be beyond the means of the troops; existing openings, doors and windows, must then be used.

buildings or trees in the vicinity should be left standing as screens from distant artillery fire.

(*b*) *Clear an open field for fire* around the building, removing and burning easily inflammable materials, collecting those suitable for barricades and obstacles, and improving existing fences, &c., which are in positions suitable for obstacles. Any hollow ways may be filled with felled trees, brushwood, or other available materials which will prevent them from giving cover to the enemy; and houses which cannot be destroyed may be burnt to prevent the enemy from firing from the upper windows.

(*c*) *Prepare a defensible enceinte* as decided on, by barricading windows and doors (except one door reserved for use, and which must be specially dealt with), making loopholes, providing flank defence and obstacles.

Inside the building, improve communications, make banquettes where necessary, place in each room a large vessel full of water, and a small vessel for drawing it: also a heap of earth to throw over any parts of the rooms which may be set on fire during action.

Store provisions and ammunition.

Set apart a place for a hospital, and prepare latrines.

If the house is liable to be attacked by artillery, it may be of some use to shore up the floors, and to spread 3 inches of earth on the boards.

If the house be very large and strong, and if it is to be held to the last, arrange for step-by-step defence, by loopholing partition walls and upper floors, and providing movable barricades to cover the retreat from one part of the building to another. It may occasionally even be advisable in such a case to remove the stairs and to substitute ladders; but ordinarily the defence would lose more by such an arrangement than it could hope to gain by the additional obstacle.

If the upper floor be used as a reduit, the garrison of the ground floor must not be allowed to retreat upstairs *after* the enemy has penetrated below.

(*d*) In cases where a distant artillery attack is to be feared, provide shelter trenches for the garrison outside the building, usually on its flanks. Existing fences or folds of the ground may answer the purpose. An outer line of defence should never be prepared from which the garrison is to retreat *into* the house. Should an outer line be desirable, as often will be the case, its defenders, if overpowered, should retreat *past* the house, exposing the pursuers to its fire.

Details of Defences.

352. *Barricading doors and windows.* Of the many ways in which doors may be barricaded, the following are some of the best:—

(1.) Fill boxes, cupboards, barrels, &c., with earth, or better with bricks or stones, and place them against the door inside.

(2.) Build a wall of bricks, or place flagstones or hearthstones against the door inside; inside this, and to support it, place one of the inner doors of the house taken off its hinges, and either strut it, or, if there be a passage leading to the door, secure it by a strong bar passed through holes in the walls of the passage.

(3.) If a railway be near, pile sleepers laid horizontally one upon another on the doorsill so as to make a wall of timber outside the door, in contact with the wall (for ordinary doorways sleepers may be sawn into two lengths). Keep the sleepers in place by two or three rails placed vertically outside them, and sunk 3 or 4 feet in the ground and firmly rammed. Horizontal loopholes may be left between the sleepers, by nailing blocks of wood on one of them at the proper level. The rails may be held in position and the whole structure made secure by tying them firmly with telegraph wire to corresponding vertical posts inside.

(4.) Timbers may be laid horizontally upon one another against the wall *inside* the doorway, and spiked to vertical ribands which are held at the foot by blocks nailed to the floor, and at the top by struts.

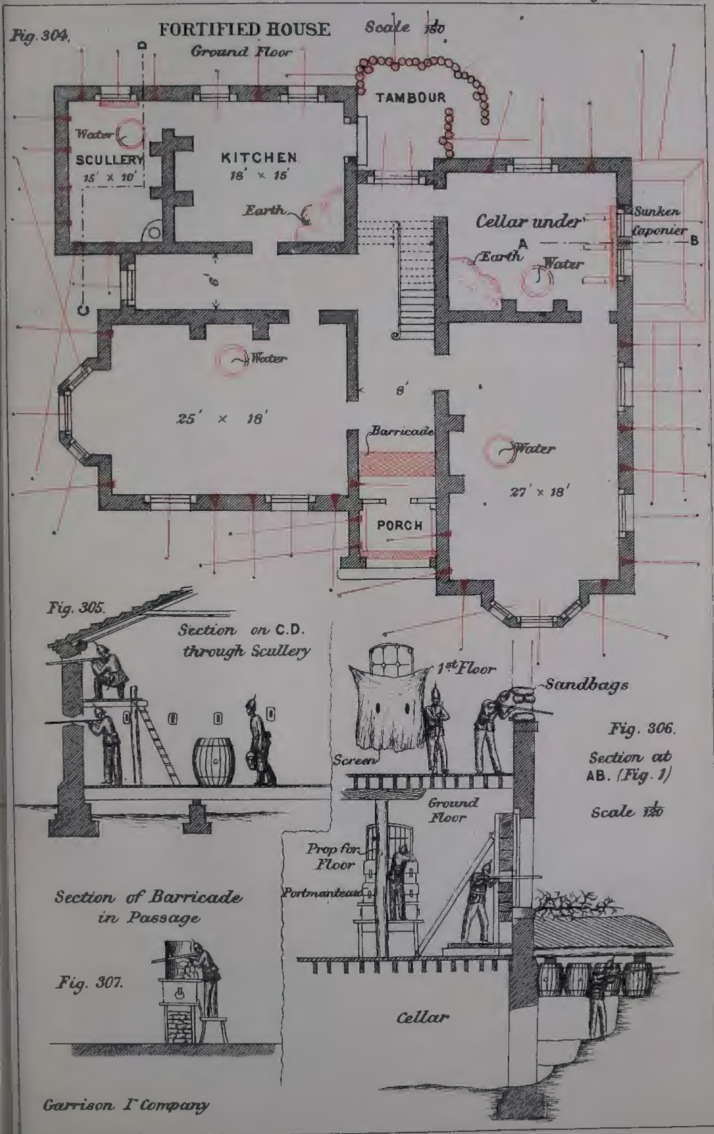


Fig. 304.
FORTIFIED HOUSE
Ground Floor
Scale 1/180
TAMBOUR
Water
SCULLERY
15' × 10'
KITCHEN
18' × 15'
Earth
Cellar under
Sunken Caponier
A
B
C
D
Earth
Water
6'
Water
25' × 18'
8'
Barricade
Water
27' × 18'
PORCH
Fig. 305.
Section on C.D. through Scullery
1st Floor
Sandbags
Fig. 306.
Section at AB. (Fig. 1)
Scale 1/120
Screen
Ground Floor
Prop for Floor
Portmanteau
Section of Barricade in Passage
Fig. 307.
Cellar
Garrison 1 Company

Many other methods will suggest themselves, which may be found more suitable under special circumstances.

Windows may be barricaded by similar means. If there are shutters they should be made use of. Generally it will be found convenient to barricade *inside* if the shutters are inside, and *outside* if the shutters are outside.

The door reserved for use should be in a re-entering angle of the house, if possible. Often a door may be selected which is so situated that it cannot be fired into from the outside; if otherwise, a cupboard or wardrobe, or a couple of chests placed one on the other, filled with earth or bricks, may be used to secure the door from being fired through or burst in. Sometimes the door may be made bullet-proof by nailing timber or iron on it, and be secured by strong struts or bars; but as 5 or 6 inches of hard wood, and three times as much of soft fir, or ½-inch iron are necessary to keep out bullets, it evidently is not an easy matter to provide them for the object in view.

If a door be so strengthened, the extra thickness should be nailed on the side towards which it *shuts*, or it will prevent it from opening properly.

The entrance should have double defences, if possible, either by a tambour outside, or by an inner door in the hall, flanked by loopholes in the side walls and in the floor above.

The windows on the upper floor generally require only to be made bullet-proof, and to a height sufficient to cover men's heads. Bedding used to be recommended for this purpose, but it is not proof against modern rifles. It will be better to use bricks obtained from openings in partition walls (often required to improve the communications), or hearthstones, kept in place by the shutters and planks, or articles of furniture. If timber be used it may be placed vertically, nailed to horizontal ribands strutted back to the floor.

353. *Loopholes* on the lower floor should be horizontal, when they can be so arranged, and vertical on the upper floor, so as to allow as much lateral range as possible to the grazing fire from the lower floor, and as much depression as possible to the fire from the upper floor. The arrangements suggested for barricading are suited to this formation of loopholes in the doors and windows. The number and situations of the loopholes will depend on tactical considerations as before mentioned. Generally it will be advisable to make more loopholes than can be used by the garrison at one time, so as to allow of increasing the fire in any direction according to circumstances.

The minimum distance apart of loopholes depends on the thickness of the walls and their strength—4 feet is the ordinary interval, to be increased to 6 feet in the case of thick walls loosely built; it may be reduced to a pace in good 9-inch brick walls, if desirable. Very thick walls, such as those of churches, cannot be loopholed; the fire must be delivered from the windows and doors, and possibly from the roof.

On the ground floor the loopholes for direct fire should not be less than 6 feet above the ground outside, but loopholes for flanking fire may often be advantageously made near the ground, so as to avoid dead angles. The floor must be broken away inside so as to allow of men using these low loopholes. Loopholes at the angles of a building are specially necessary when the angles are not flanked. Several tiers of fire may be arranged in such a case at the angles, care being taken not to weaken the building so as to endanger its stability. Banquettes, where necessary on the ground floor, can generally be made with furniture and planks, but they should be firm and steady. A commanding line of fire for men in close order may often be obtained, with very little labour, by removing tiles or slates from just above the eaves of the roof, so that the men fire over the top of the wall.

Ventilation and Light must be secured by leaving openings at the tops of the windows when barricading them; by smoke-escape holes through the wall, under the ceilings in top stories; or in buildings with only one floor, by removing tiles or slates, and by breaking the ceiling away, if there be one.

354. *Flank Defence and Obstacles.*—A good obstacle is generally to b preferred to flank defence, if the choice lies between them; but the combinatio of both is always desirable. To create flank defence where the form of the build ing gives none naturally, machicoulis galleries or tambours may be used. Th tambours may be either open stockades or sunken caponiers, roofed over.

These sunken caponiers (see Fig. 310) have the great advantage of bein almost safe from artillery fire; they are, however, inapplicable when the groun is uneven. An open stockade is always a weak point in the defences, bein peculiarly liable to assault; but it can be constructed with less skilled labour tha a machicoulis. A machicoulis gallery has the advantage of delivering its fi from loopholes so placed that they cannot be fired into by an enemy at a distance

355. *Machicoulis galleries,* Fig. 307*a*, are easily prepared, when the hous has balconies, by making the parapet musket-proof by hearthstones, bags full o earth, &c. If there be no balconies an uppe window must be used, the wall below it bein broken down to the level of the floor. Tw beams or strong poles are laid on the floo and the ends pushed out 3 or 4 feet throug the opening, the inner ends firmly lashed o spiked to the floor joints. On these suppor planks may be laid and a parapet built. four-legged table, laid on its side, will form good support for a parapet of hearthstones an bags of earth; one or two men can fire dow wards, sitting or kneeling on the floor, an protected by the parapet.

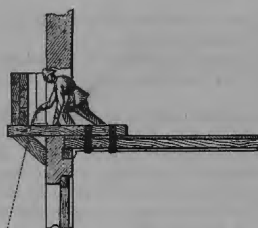


Fig. 307A.

356. *A stockade tambour,* Fig. 308, ma be from 6 to 9 feet broad inside, and lon enough for three or four men firing each way. The earth taken out of the trenc in which the timbers are planted should be thrown inside to make banquettes, and if possible the work should be roofed over.

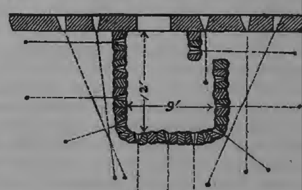
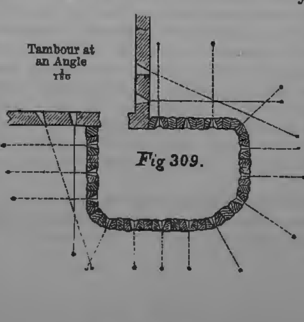


Fig. 308.—Tambour at Middle of a Wall, $\frac{1}{180}$

To flank great lengths of wall, tambours should be made long enough for four, five, or six men firing each way.

Existing openings should be used, if possible, to communicate with tambours or machicoulis. Occasionally, however, it may be well to construct a tambour at the corner of a building, as in Fig. 309, where an opening must be made to communicate with it. The *hea* of the tambour should be flat or nearly so, as in Fig. 308; the *obstacle* may b traced so as to be flanked from th building.

Tambour at an Angle $\frac{1}{150}$



357. For a sunken caponier tam bour applied to a house it is almos essential that there should be a underground storey, otherwise th access to it will be difficult. Thi would not be requisite, if it be applie to an enclosure wall. The excavatio as in Fig. 310, may be $3\frac{1}{2}$ feet dee 6 feet wide, and from 6 to 9 feet long One or two logs laid on the groun on each side of the excavation ove which the men fire, raise their parap to 4 feet 6 inches. Three or four transverse logs are now laid on these, slightly notched, and secured with dogs, spikes, or lashings, and again three transverse to the last, all secured in a similar manner. On the last set of timbers are laid

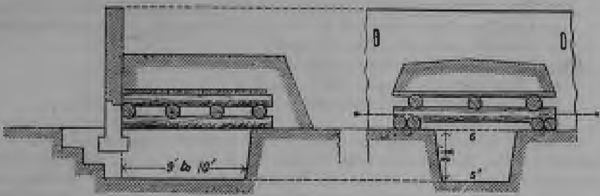


FIG. 310.—Sunken Tambour, Sc. $\frac{1}{120}$.

planks or beams, and the whole is covered with the earth from the excavation, the end farthest from the wall being banked up with earth. There are thus long horizontal loopholes left between the transverse logs a foot above the ground. The access is by an opening in the wall of the basement.

358. *Obstacles* are always advantageous, but they are *specially valuable at night*. The best obstacle, if it can be procured, is a good abatis. In default of materials for this, palisades, wire entanglements, pickets, or any other means at hand, such as fences, pieces of water, shrubberies, &c., should be used and improved. It is generally recommended that small ditches should be dug outside doors and windows; this, however, is labour thrown away, the obstacle being insignificant; nor is such a small ditch formed all round the building (the excavated earth being banked up against the wall) of any value, either as an obstacle, or for protection against artillery fire or against breaching by gunpowder or other explosives.

In preparing obstacles, the approach through them to the door reserved for use should be made as circuitous as possible and under a cross fire.

The line of obstacles should be continuous, at least opposite the weaker parts of the building, and should be connected with the walls at the ends, and also at intermediate points, if possible, in order that it may not be turned, or that an enemy having penetrated at any point may not extend close to the wall, under the defenders' line of fire.

DEFENCE OF VILLAGES.

359. The use of villages as supporting points or pivots in a defensive line has already been referred to in Art. 218.

As this kind of defence is wasteful of men, it must always be decided whether villages would require more men to hold them than their tactical position may be worth. On this point it may be observed that it frequently happens that a village is important *only* because roads pass through it; and if on examination it should appear that a better position for defence exists outside the village, it will evidently be best to fortify that position in preference to the village.

Such cases frequently occur in highly cultivated and enclosed countries like England. Hedges, banks, and fences have much greater capabilities of defence than the weakly constructed and scattered buildings of which so many English villages consist.

360. Their principal recommendations are :—

1. That they can be made defensible in the shortest time, and admit generally of protracted and obstinate defence.

2. They conceal the numbers and dispositions of the garrisons and of the troops in rear of them; and often cover the reserves from fire.
3. They afford shelter to their garrisons beforehand.

361. Their disadvantages are:—

1. The scattering of their garrisons, and consequent difficulty of supervision.
2. Liability of the defenders to loss by splinters, &c., under artillery fire.
3. Liability to be set on fire by shells.

362. The object of holding a village may be—

(*a*) As a pivot in the main line;
(*b*) As advanced post or outpost; or,
(*c*) As a reserve post.

For any of these purposes, the same general rules are applied to them as to earthworks under similar circumstances, viz.: If in the main line (*a*), they should be strongly fortified on the front and flanks, and capable also of resisting the attack of infantry at the gorge, so as to give time for the reserves outside them to act. If in advance of the main line (*b*), their distance from its supporting fire will determine whether it is to be obstinately defended or not, and therefore how much of the circumference must be fortified. If in rear of the main line (*c*), an obstinate defence is sure to be required all round.

363. The suitability of villages for defence depends upon—

1. *The form and nature of the surrounding ground*, which should be such as not to include commanding positions within close range; to afford a clear field of fire with a small amount of labour; and, if necessary, to permit of the unimpeded advance, in the desired direction, of the troops outside the village.

2. *The shape of the village and nature of the houses, &c.*

The suitability of form to the tactical position affects considerably the time required for preparation as well as the obstinacy of the defence when prepared. Straggling *hamlets lying end-on* to the enemy (Fig. 311, Plate XXXV.) can be made very strong against flank attacks, but are easily raked by fire and require much artificial addition in the form of shelter trenches, &c., thrown out in the flanks so as to increase their frontal fire; their length also may be so great as to weaken the support they may derive from positions in rear of them, in which case it may be necessary to abandon and destroy, as far as possible, the more advanced portion of the place, and to retire the main line of defence towards the centre.

Similarly, villages *broadside-on* to the enemy (Fig. 312, Plate XXXV.) are strong in front and safer from the effects of fire, but require more attention on the flanks and can be less easily retrenched, whereas those of a circular form are suitable for all positions (Fig. 313, Plate XXXVI.). The nature of the materials of which a village is built must be considered as to whether it is likely to be set on fire by the enemy's shells.

364. *Arrangements for the Defence.*—The difficulty of expelling an enemy who has once got into a village makes it especially necessary—

1st. To hold the boundary obstinately by a well-extended shooting line, with its supports and small reserves ready to reinforce or to expel the enemy.

2nd. To organize a second line in case of the failure of the first, and perhaps a keep.

3rd. To have easy and well-arranged communications to ensure prompt action of the supports and reserves, and orderly retreat to the interior lines of defence.

365. The infantry garrison may be reckoned at *two men* (one man being the minimum) per yard of the circumference to be defended; this allows for reserves. Field or machine guns, and engineers, in addition, as required; the guns depending on the facilities for making use of their long range, and for their safe withdrawal when capture becomes imminent; the strength of the engineers depending upon the amount of skilled labour and demolition by explosives that may be required.


A SALIENT VILLAGE
Prepared for Defence.
Attack
Prepared for demolition
Fig. 311
Counterattack by Outer Reserves
Counterattack
House prepared for defence.
Abatis
Shelter trench
Loopholed Wall
Clearing
Entanglement
Wooden Buildings
Barricades
Wire Entanglement
Scale 6 to 1 mile
100 0 100 200 300 400 500 Yards
Fig. 312.
BROADSIDE VILLAGE

CIRCULAR VILLAGE.

Fig. 313

Fig. 314.

The troops should all be told off by companies and half-battalions or battalions, to fortify and defend different parts of the village.

The bulk of the garrison (say two-thirds or three-fourths) should furnish the shooting line with its supports, occupying the circumference to be defended.

366. The foreground should be, as usual, cleared, and obstacles plentifully used at weak points. The roads should be blocked within effective range, and barricaded at their entrance to the village; houses flanking the barricades on either side being prepared for defence.

367. *Barricades in Streets* (Figs. 315-16).—Streets are barricaded by forming across them an obstacle, which should also serve as a parapet.

At first a rough obstacle may be formed by a line of carts with their wheels taken off, furniture, casks, and any available objects at hand. Trees, if growing alongside a road, should be felled and used as abatis.

As time permits, a parapet of suitable available materials should be constructed. Casks filled with earth form a good parapet. If artillery fire is feared, a ditch should be dug in front, and the earth used as a parapet, to which the casks would form a revetment; chairs, &c., should be used as a banquette. Head cover should be provided for the defenders.

The barricade should be flanked, both in front and rear, from loopholes in the adjacent houses or walls; communication being made from house to house on each side of the street, to allow of fire being kept on an advancing column, and to enable the flanking parties to retreat. The loopholes should be arranged so as not to fire into each other, and the defenders, on being posted, should be cautioned as to the direction of their fire.

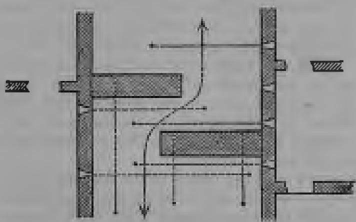


Fig. 315.

Passages, to allow of the advance or retreat of outposts, are generally required through barricades. This can be arranged by making the barricade (as in Fig. 315) in two parts, overlapping each other, the interval between them (which is easily closed by a movable obstacle, such as chevaux-de-frise) serving for the passage of troops; or (as in Fig. 316) by building the barricade in one length, at a spot where some parts of the houses are conveniently retired from the general line of buildings, so as to afford a communication round the end of the barricade.

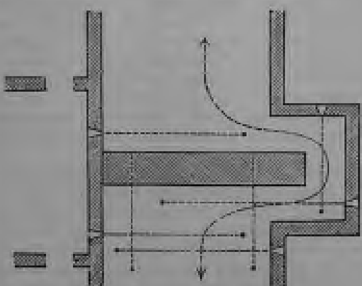


Fig. 316.

Any obstacles used in advance of the barricade should also be formed so as to leave openings for troops to pass through.

368. The shooting line should, as a rule, obtain their cover clear of the houses, so as to reduce the losses from splinters off the buildings struck by shell; it is considered that a distance of about 40 yards (minimum) will ensure this. Existing walls, hedges, &c., will be utilized as described in Chapter I., Art. 153, &c. The usual irregularity of form of such enclosures frequently favours a good flanking defence, which should always be looked to as a safeguard against the enemy's attempts to break through the first line; but the essential requisite is a powerful *frontal fire* on the principal line of attack. Shelter trenches, with obstacles in front, if possible, supply the place of walls, &c., when such do not exist, or do not happen to be favourably situated. If the front be an extended one, much flanking power may be obtained by small earthen redans, lunettes, or sunken caponiers, placed in front of the first line, and generally so as to close a main thoroughfare. These works are also of great service in the event of an intended sortie from the village.

369. During the artillery fire preceding the attack, and while the attacking infantry is yet out of effective range of small arms, it will be desirable to keep the shooting line well covered; in trenches they will be very fairly so, but behind walls it will be often necessary to provide either field casemates or deep shelter trenches. A few sentries left on the front line will watch the attack.

370. It is not advisable, though it may be necessary, to place guns in the shooting line, on account of liability to capture, and frequent difficulty of retreat from a much exposed position. They should rather be on the flanks, somewhat retired, giving a cross fire on the field of attack, and commanding the roads (Fig. 311, Plate XXXV.), or on high ground in the rear.

371. A portion of the troops of the shooting line must be, as usual, told off as supports, their duty being to make good losses, and to help in driving out the enemy in case of partial penetration of the first line. Their numbers need hardly ever exceed half the shooting line; they must be covered from fire, either in the field casemates or deep trenches (before mentioned), or behind buildings close at hand when this cannot be done with safety.*

372. To make additional provision against the partial penetration of the first line by small bodies of the enemy, short lengths of wall, hedges, &c., which may run perpendicularly to the shooting line and in rear of it, may be prepared for defence, in order to prevent the assailants, who may have forced their way in, from spreading along the line. This arrangement also favours the division of the place into defensive sections.

In case of the failure of the first line, there may be a second (and even a third) line of defence, manned at its principal salients by troops from the reserve; behind this line the beaten troops retire by well-defined routes, forming again, either to aid in its defence, or as a reserve.

373. The cover for this line or lines will usually consist of an irregular line of loopholed walls and houses, made as impenetrable as possible; where roads cross the line they should be barricaded. Here the fighting will be almost hand to hand, and a close flanking fire is especially valuable. Houses, &c., close in front of this line should be demolished, or their use denied to the enemy by cutting away the floors, clearing the window openings down to the ground, &c., to prevent the enemy from closing in order to make breaches by means of explosives or otherwise. The same precautions as to small bodies for charging the enemy in case of penetration, may be taken as with the first line; and a few of the houses, at favourable flanking situations, may be loopholed and barricaded all round, to act as section keeps.

374. *When a village is intended to be held to the last*, though surrounded by the enemy, a substantial building or group of buildings and enclosures may be prepared for defence as a keep to the whole. Here a few resolute men must hold out till assistance arrives. It is evidently useless to prepare a keep if such desperate resistance be not intended. The real object of the keep is to facilitate recapture by having one foot, as it were, in the place; and as its garrison cannot be large, and must be (unlike the retrenchments) kept separate from the rest, it could not obtain this result unaided.

375. Buildings with thick walls, and having a good form for flank defence,

* Troops *in* an ordinary house are not safe under artillery fire, unless in cellars. *Behind* the house they would not suffer much, as the shells would usually be exploded in penetrating the outer wall.

are the best. They should be well out of view of the enemy, and, if possible, sheltered by neighbouring houses, &c., from distant artillery fire. Close artillery fire is hardly to be feared, as the constant fire of rifles from the loopholes of the keep would make the service of the guns almost impossible. Churches and large stone houses generally answer well as keeps.

376. The communications are of the utmost importance; they should provide the means of moving easily all along the front of the various defensive sections, and also in a radial direction for the rapid advance of supports and reserves. Finger-posts must be freely used to direct, and, if necessary, orderlies must be posted at important points for the same purpose. No communication should pass through the keep.

377. A few of the garrison should be told off to take the best measures for extinguishing all fires, having water ready at hand.

If possible, not less than a company (or at the very least a half-company or section) should be told off to any defensive section. The keep would require from one company to half a battalion.

378. Machine guns would be very usefully placed behind barricades, to sweep long, broad streets. Care must be taken that they are not exposed to the enemy's artillery during the early part of the fight.

Some of the houses should be used as guard-houses to furnish the ordinary guards.

A bomb-proof building in a sheltered situation should be fitted up, or purposely constructed for the accommodation of the sick and wounded.

379. The arrangements for the defence, in order of relative importance, are :—

1. Clearing the field of fire.
2. Covering the shooting lines, supports, and guns.
3. Placing obstacles.
   (Part of 3 would generally go hand-in-hand with 1).
4. Making communications.
5. Constructing retrenchments and keeps.

The salients of the first line of defence are its most important parts; next the flanking and re-entering portions. After this the closing of all gaps by obstacles, as well as making obstacles in the foreground.

With an adequate garrison, a period of about 12 to 18 hours would generally suffice to fortify a village strongly.

380. The figures in Plates XXXV. and XXXVI. illustrate the foregoing remarks.

Fig. 314, Plate XXXVI., shows the distribution of troops for the defence. This village was the scene of a combat in the war of 1870-71, when it was held by the Germans against a sortie of the French from Paris. The defenders were posted much as here shown, but sufficient care had not been taken in occupying the farm at *b*, and blocking the hollow roads near it; a wall at *a* had also been left standing. Owing to this, the French managed to take the farm, and, though they pushed their attack no further, its recapture cost many lives, and was mainly brought about by the failure of the sortie in every direction.

381. *Defence of woods*, Plate XXXVII.—The fortification of woods is similar in principle and general arrangement to that of villages. Woods are very effective in screening the defenders from view, and give more or less cover, according to the size and closeness of the trees; this very closeness, however, is a hindrance to the united action of the defenders, and makes it extremely difficult to expel an enemy who has once gained a footing in the wood. Moreover, the construction of lines of retrenchment for further resistance is a work of more time and difficulty than is the case with villages. Therefore the main object of the defence is to hold the edge of the wood very strongly, and to take special steps to ensure the prompt action of supports and reserves in case of the boundary being forced at any point.

Well-timed flank attacks by the reserves (however small) are of great service in repelling an enemy who is trying to force his way through.

382. The same garrison may be assumed as for villages, viz., one to two men per yard of circumference defended. They should be told off to different sections in tactical units, the bulk of the men being in the shooting line.

Whether the shooting line should occupy the whole edge or only portions, must depend upon the size of the wood and the difficulties of approach; but in any case it is advisable to provide an obstacle all round the boundary, if possible. It is generally best to leave the outer trees standing, and to form the obstacle by packing in between them trees, boughs, and underwood, procured from a cleared belt some 10 or 20 paces inside the edge of the wood; thus forming at the same time the necessary communication for the defenders. Large trees should be left alone; they give cover to two or three men, and require skilful woodmen to cut them down. The most important parts of the boundary are the salients first, and then the re-entering angles; the former are, as it were, the bastions, and the latter provide flanking fire to the former. Additional obstacles in the foreground to increase the effects of fire, without screening from it, would be useful.

The shooting line obtain cover behind the abatis in trenches, or adapt hedges and ditches where such exist.

The supports and reserves are safe if so far in that they cannot see the open between the trunks of the trees; otherwise, or if the timber be not sufficiently close or well grown to resist rifle bullets, they must be covered by trenches or log walls.

Entrances of roads must be barricaded with felled trees, or, if communication is to be preserved, the barricade must be in advance of the general line of obstacle, leaving passages on either side; or an earthen redan or lunette may cover the entrance (Plate XXXVII.).

383. If a wood is supported by artillery, the guns are better placed outside on the flanks, as in the case of villages; if unavoidably placed in a wood on the boundary, they should be spaced at wide intervals and near good roads, either existing or made on purpose, by which to retire. They should be concealed from the enemy, and each gun should have two or more places from which it can be fired at pleasure.

To localize the combat after penetration of the boundary at any point, lines of abatis should be made perpendicular to the boundary, and extending from 50 yards to 100 yards inwards: these radial retrenchments may with advantage correspond with the tactical divisions of the defenders.

Any open spaces, brooks, or broad roads running through the wood in a direction parallel to the front may be taken advantage of to form a second line, secured against a rush in the same way as the first line—by abatis and other obstacles on the front and flanks, leaving as much clear space in front as possible for fire effect. A good-sized building or enclosure would form a keep.

384. Communications are of the utmost importance, and the roads and paths selected or made for the supports, reserves, and guns may be well defined by *blazing* the trees with an axe, and by leaving sentries in addition at crossings to give directions.

In dense woods preparations should be made for blocking the roads, in case of retreat, by cutting trees on either side nearly through in readiness to be pulled down across them, leaving the upper part still hanging to the trunk to prevent their being easily pulled aside.

Besides these radial communications, there must always be the means of moving freely along the boundary.

385. *Special Positions in or near Woods.*—If a position must be taken up in the midst of a wood, it is treated in the same way as a retrenchment.

If the rear boundary is to be held, the same rule applies, care being taken to leave a narrow belt of trees behind the clearing, to screen the defenders.

DEFENCE OF WOODS.
Attack
Fig. 317
F
F
S
S
R
S
S
R
M
M
K
t
Clearing
m
n
L
Attack
Attack
WOOD
PREPARED FOR
DEFENCE.
Scale, 12" to 1 mile.
F. F. Field Caponiers
L. Open Lunette to cover Entrance
M. Gatling Gun
Field Gun
Communications
S.S. Supports
R.R. Reserves
m. n. Retrenchment
K. Keep
Shooting Line
t. Tambour
GARRISON
2 TO 3 BATTALIONS
6 GUNS.

When the occupation of a wood would lead to too great extension, a fortified position should be taken up in rear of it within effective range of rifles (600 yards), the trees on the near border felled to form an abatis as an obstacle to egress, and the roads strongly barricaded.

A heavy fire of guns and rifles should be directed on all the most probable points of egress.

Should the enemy succeed in setting a wood on fire to any considerable extent it must be evacuated, and the position "behind the wood" taken up as quickly as possible.

These remarks apply also in principle to positions in rear of villages.

386. *Attacking a Fortified House.*—A house may be attacked by infantry by day or by night; or a combined attack by infantry and artillery can be made.

An Infantry attack by daylight would probably be made by advancing skirmishers, and gradually strengthening them until they formed a long enveloping line of marksmen, lying down under cover if possible, and concentrating their fire on the loopholes of the front to be attacked. Protected by their fire, the storming party would advance, accompanied by engineers or a working party with axes, sledge-hammers, gun-cotton, and whatever means are available for removing obstacles and forcing an entrance.

The advance would be made over ground on which the defenders' fire was weakest, probably at a salient; and having penetrated the line of obstacles at that point, the assailants would endeavour to extend close to the walls under the line of fire of the defenders, and so grapple with and bend their rifles. If flank defence existed, it would be neutralized as far as possible by a concentrated fire on the loopholes. The entrance would not be attempted at a salient, which would be difficult, but at a door or window, or by breaching the wall with gun-cotton.

A tambour might offer an easy access to the interior of the building if it were low or weakly constructed.

Once inside the building, if the defenders still resisted, it should be set on fire, or they should be smoked out.

Two or more attacks should generally be made at the same time, to distract the attention of the defenders and to multiply the chances of success.

387. *An Infantry attack at night* is more likely to succeed than by day, because the approach can be made with little or no loss. It is only while the attacking party are removing the obstacles and endeavouring to force an entrance that the defenders' fire will be effective.

The attack should be made by surprise as far as possible, and a previous reconnaissance is of great importance to avoid mistakes and confusion in the dark, and to know what provision is suitable to be made for overcoming obstacles. The troops should be assembled secretly, as close to the building as possible, and the different columns of assault would move directly and silently to their prescribed points of attack. If breaches are to be made by gun-cotton or gunpowder, every effort should be made to place the explosive and to ignite the fuses before the attack is discovered, and to assault immediately the explosion has taken place.

The assailants should not stop to fire, but should endeavour to come to close quarters at once.

388. *A Combined Attack of Infantry and Artillery on a House Screened from Distant Artillery fire* would commence in the same way as the unaided infantry attack by day; but as soon as the fire of the infantry had established a decided ascendancy over the fire from the building, two or more guns would be brought up into line with them, screened as much as possible by the slopes of the ground, trees, &c., and by their fire break down obstacles, breach the building, and set it on fire. When the artillery fire has prepared the way, the assault should be given, if the garrison has not previously succumbed.

389. *A Combined Attack of Infantry and Artillery on a House Exposed to Distant Artillery fire.*—The artillery commences the attack, concentrating the fire of all available guns on the building. This fire would probably drive the defenders from the building. If it also ruins it and sets it on fire, the infantry on their approach will only have to deal with the defenders of the outer line of defence, if there be such. If, however, the building should still be defensible when the attacking artillery is obliged to cease fire owing to the near approach to the building of their own infantry, and the attacking infantry cannot force their way in, it may be necessary to bring some guns up to within musketry range to breach the building.

390. *Defending a House against Assault.*—In the case of an infantry attack by day, accurate fire from the building should hinder the approach of the enemy, and inflict loss upon him; and should he succeed in establishing an overpowering line of fire, it would be good policy to withdraw the men from the loopholes until the storming parties advance, and then to concentrate fire on them, particularly while checked by the obstacles. This fire, as rapid as possible, must be very deadly, and will probably beat off the attack.

391. In the case of night attack by infantry, surprise should be avoided by all possible means, particularly by careful patrolling; and any attempt to lodge explosives against the walls secretly must be carefully guarded against. When the attack takes place, a grazing and flanking fire on the obstacles round the house, delivered as rapidly as possible, must inevitably take effect, and will probably frustrate the efforts of the assailants.

392. In defending a house against a combined infantry and artillery attack, when the artillery cannot open fire until within effective rifle range of the house, it will generally be best to reserve the fire of at any rate a portion of the garrison until the guns are brought up, and then to concentrate fire on the gun detachments, and finally on the assaulting columns.

In the other case where artillery can open fire at a distance, the garrison should generally be removed from the building during the cannonade, and be placed in shelter trenches beside it, or under cover in rear, until the near approach of the attacking infantry compels their artillery to cease firing, when, if the buildings are still tenable, they should be rapidly occupied again, and the entrances (which should in this case be sufficiently numerous) barricaded. Should the building take fire *during the cannonade*, a party should be told off to extinguish the flames.

Attack and Defence of Field Works.

393. The attack may be made either by—

A. Storming.
B. Surprise; or exceptionally by
C. Cannonade only.

Storming.

The attack should be preceded by as full a reconnaissance as possible, to ascertain the best line of approach, the strength of the garrison, and the numbers and positions of the outer reserves. The officer commanding the engineers concerns himself with the details of the works, considering the best points of attack, the obstacles to be encountered, the strength and composition of the working parties, and the tools they must carry. The officer in command of the artillery looks to the best positions for his guns with respect to the following points:—

(*a*) To enfilade the lines, especially such as have trenches in rear of the parapets.

(*b*) To fire on the ground behind the lines, with a view to searching the roads of approach of the outer reserves.

(*c*) To avoid, as far as possible, the necessity of moving the guns.

As an introduction to the attack, the enemy's outposts must be driven in sufficiently far to allow of the construction of the batteries or gun-pits on the chosen positions without exposure to the enemy's riflemen.

394. The attack which follows may be divided into four periods, viz.:—

1. The cannonade.
2. The advance of the storming columns to the glacis.
3. The storming of the parapets.
4. The capture of the interior, and securing the works against recapture.

395. A heavy converging artillery fire from a superior number of pieces, at a range not exceeding 2,000 yards, and less if practicable, is essential to the success of the attack.

The objects of the cannonade are:—

(*a*) To reduce to complete silence the artillery in the works or in the intervals which may be directed on the attacking troops, especially those which flank the near approach to the works. If the guns are found to have been withdrawn under cover into gun-recesses and blindages, efforts must be made, by indirect and other fire, to destroy the platforms, to choke the embrasures, and generally to render the gun-portions unserviceable.

(*b*) To damage the works. Complete destruction of earthen parapets cannot be effected by the fire of field guns, although with the smaller profiles (under 9 feet thick) a breach can be made in any one spot by a concentrated fire of many guns on it.

The principal object, therefore, is to cut down the crest and to produce irregularities in the superior slope, destroying loopholes and other means of covering the defenders' heads, and making the parapets inconvenient for use during the close fight. A work damaged by a heavy fire will always impair the confidence its defenders may have in its powers of resistance.

The destruction of the escarp, to facilitate scaling, is effected by the indirect fire of shells grazing the crest of the glacis. If the works are sufficiently well known, gates and palisades at the gorges can be destroyed also by indirect fire.

Obstacles in the foreground can only be damaged if exposed to view. It is difficult to produce any real effect on abatis, pits, or wire entanglement. The former, if very dry, may be set on fire, but it must not be burning when the assault takes place.

(*c*) To harass and inflict loss on the garrison. As during the cannonade the garrison will be close under the parapets and in the blindages, they are chiefly to be got at by an enfilading fire, which has the advantage that it can be kept up until the stormers are very close to the works. By keeping up an incessant fire the garrison are to some extent prevented from showing themselves, and from observing and resisting the approach of the stormers.

When the stormers have arrived so close to the works as to be in danger from the fire of their own artillery, the latter must be directed against the flanking and supporting works, and on the positions of the outer reserves.

396. *Second period—advance of the Infantry.*—The advance of the infantry is effected in the manner described in the "Field Exercise," the crisis of the fire combat occurring as close to the works as possible.

Accompanying the supports would be the working parties, provided with tools and expedients for surmounting obstacles; and in rear of these again is the main body of the stormers. A second attacking line follows, at a distance of 300 to 500 yards from the first, to engage the outer reserves.

397. When the rapid independent fire of the assailants has begun to tell, and the fire from the parapets becomes slack, a rush must be made for the ditches of the works. This should be done by a portion of the attacking line, in order that the fire on the defenders may not cease altogether; the working parties advance with them to clear away obstacles. If none are encountered on the glacis, the stormers rush at once into the ditches; if otherwise, the obstacles must be first removed by the working parties, or gaps about twenty-five paces wide must be made for the passage of the stormers. All this time some of the assailants keep up a fire on the defenders of the parapet whenever they show themselves. Any flank attacks now made by the defenders' outer reserves must be met by the troops detailed for the purpose, so that the storming columns may be uninterrupted in their work.

398. The passage of the ditches can be facilitated by bringing up with the assaulting columns sacks of wool, shavings, &c., or bundles of hay or straw, or fascines; these thrown into the ditch will fill up a portion and assist in forming a passage over it. The fascines in this case may be short, cut into 6-feet lengths, so that a man can run over rough ground carrying one or two of these fascines besides his arms and accoutrements.

399. An *abatis* of green timber is most difficult to demolish; artillery fire will have produced little effect on it, and the only way of forcing a passage is to work with axes at the stakes by which the trunks of the trees are fastened, and then by means of ropes to draw out disentangled portions. To effect this under fire is scarcely practicable. Lengths of powder-hose filled with gun-cotton discs or granulated gun-cotton, and thrown to the abatis and detonated, will clear away some portions of the obstacle. If the abatis be made of dry wood, breaches may be made in it by this means. If dry, the abatis may be demolished by firing incendiary shells into it, or applying petroleum and setting fire to it.

Palisades and *fraises* may be destroyed by using axes, if the flank fire protecting them can be subdued. Powder bags will make casual gaps in them, and pipes or hose, filled with gun-cotton and detonated, will cut them down level with the ground.

Chevaux-de-frise can only be removed by being rolled over to one side, and if they have been secured together by chains or stout wire, it takes a considerable time to clear them away.

Entanglements and *Military Pits* can be surmounted by making roadways over them with doors, wide planks, hurdles, or bays of boarded fencing.

If the ditches are defended by caponiers or galleries, the assailants endeavour to drive the defenders from the loopholes by inserting firebrands, and the moment a loophole is cleared, plugging it up with wooden wedges, or bags of hay, &c.; or the caponier or gallery may be breached with explosives.

In the case of sunken caponiers, the loopholes of which are close to the bottom of the ditch, fascines, &c., can be thrown down in front of them to mask them.

400. *Assault of the Parapets.*—By the time the obstacles have been surmounted, the main body of the stormers will have arrived, and the assault must now be given with energy on as large a front as possible. The stormers, after having assembled in sufficient numbers in the ditch or on the berm, rush over in a body and mix with the defenders in a hand-to-hand encounter, following them pell-mell into the retrenchment or keep, if there be one.

If before the final rush the defenders have left the parapets, and unmasked the fire of the keep or retrenchment, the assailants lie on the superior slope and oppose the fire, while an attempt is made to open the keep by means of explosives or by main force. This will depend on the nature of the keep.

If it consists of a blockhouse, the sappers with gun-cotton, &c., should advance against the dead angles and endeavour to breach it, or to force the defenders from the loopholes, as before mentioned in the case of caponiers in the ditch. If they can manage to get on to the roof of the blockhouse by means of ladders, they may lodge mines beneath the earth covering, and on the top of the roofing baulks.

In case of mines being suspected to exist in the interior of a work, the stormers should retire to the berm or ditch, and an officer of engineers must endeavour to discover and cut the hose or wires leading to the charge.

401. After capture, the magazines must immediately be examined to see if they are prepared for explosion; the guns of the work are turned on the retreating defenders; the entrances on the gorge side are closed and the bridges torn down, and every preparation made for receiving an attack from the rear; the parapet of one of the former front faces is cut through to form an entrance. If the work is half closed by a stockade, shelter trenches should be immediately thrown up behind it to give cover against the enemy's artillery; if by a slight parapet, this must be strengthened by cutting a trench in rear and heaping the earth up against the interior slope to form a fresh interior slope.

If the work is *open*, or the gorge defence has been destroyed, banquettes may be cut in the exterior slopes of those faces from which a fire can be brought to bear on the enemy, until the slackness of his fire enables the new defenders to make a fresh gorge parapet.

If the work cannot be held, the guns should be made unserviceable, the magazines blown up, the blockhouses destroyed, platforms broken up, and gun-banks cut away.

402. *Attack by Surprise.*—To find the enemy unprepared is always so important a factor in the chances of success, that every attack by main force should, if possible, be made suddenly and without letting the enemy know of it; but sometimes under cover of weather, or when the defenders are much dispirited and their outpost duty badly performed, or when immediate support of the work by outer reserves is not forthcoming, an attack by a comparatively small force may be made with considerable chance of success. Obviously, in this case, silence and secrecy are essentials, and the advance must be made without firing a shot.

403. *Attack by Cannonade.*—In some cases the defenders may be forced to evacuate their works or to capitulate by a cannonade only, effected by an overwhelming superiority of artillery, followed, perhaps, by a heavy fusilade from swarms of sharpshooters well ensconced in the neighbouring ground. The circumstances which render such a course likely to succeed are—a depressed state of mind of the defenders, a great inferiority of strength, or badly constructed works, &c. The mode of proceeding is similar to that described for the preliminary cannonade of an actual assault.

The Defence.

404. *Against Surprise.*—Vigilance and a well-organized roster of duties, especial attention being paid to the outposts and patrols, are the best securities against surprise.

At night the barriers are shut, entrance of patrols, &c., being effected at one only.

At the first alarm all should be at their posts, and the guns loaded with case shot, ready to greet the enemy with volleys. At daybreak, especially, the guards must be on the look-out, this being the most probable time for an assault.

405. *Against Storming.*—The preparations against an attack by storm may be divided into four periods, corresponding to those of the attack.

First Period: the Cannonade.—Advanced bodies of good riflemen should be posted in sheltered and concealed places to keep the enemy's artillery at a distance as long as possible, and to pick off the enemy's reconnoitring officers.

When these riflemen are obliged to retire on the outer reserves by superior forces, the enemy's cannonade begins. The commandant of the work and the officers in command of the artillery and infantry watch the enemy's advance. A few selected good shots from the garrison man the parapets, especially at salients, and fire on officers and small bodies that venture too close.

The guns join their fire to that of the artillery of the outer reserves to oppose the enemy's artillery as it comes into action: if greatly over-matched, the guns in the works are run down into the blindages.

The infantry told off to the parapet sit or lie on the banquette of those faces which are not exposed to enfilade or reverse fire. The defenders of the flanks and gorge keep close in their blindages until the near approach of the enemy.

The reserve is kept under cover in the rear trenches and blindages.

406. *Advance of the Enemy's Infantry.*—As the enemy's infantry advances to within effective range (about 500 yards), the front faces are manned and fire on them.

The guns are run up, and open on the main bodies of the workmen and stormers as soon as they arrive within 1,500 yards: the accurate knowledge of ranges gives the guns of the defence a great advantage.

The guns all concentrate on the nearest column first, and on the others in succession, regardless of their own losses.

When the storming columns arrive within 300 paces, the flanks and gorge must be manned, and support given by the former to adjacent works which may be similarly resisting attack. The guns continue their fire at all hazards. The reserves inside the work leave their cover, and get ready to resist the assault. The fougasses, if any, are sprung as the enemy arrives within their range. When he reaches the glacis the outer reserves attack, and oppose the penetration of the intervals between the works.

407. *Fight for the Parapet.*—When the enemy is in the ditch, hand grenades* and shells are thrown over the parapets: the defenders of the parapets fire unremittingly on the enemy's riflemen, and on the stormers not yet in the ditch. All the defenders are ready with bayonets to resist the stormers; the guns fire as long as there are a gunner and a round of ammunition left.

The inner reserves are loaded and ready to fire in case of the retreat of the defenders of the parapet.

408. *The fight inside.*—If the enemy succeed in getting in and there is no keep, he must be charged by the reserve, the beaten defenders of the parapet clearing away quickly to either flank of the gorge to allow the reserve to act freely by fire and with the bayonet. The outer reserve may send assistance.

If there is a keep or retrenchment, the reserve must take care to avoid a mêlée, and should retire rapidly towards the gorge, unmasking the fire of the keep. On no account must the defenders of the parapet, or the reserve, retreat into the keep; it is best if there be a place of assembly for them in rear of it.

After the fire of the keep has taken effect, the defenders may make an effort to drive the enemy back again over the parapet; or if a retreat be necessary, the keep covers that of the garrison of the work, and finally, that of the defenders of the keep is covered by the outer reserve.

409. *Attempt at recapture.*—Any attempt at recapture of a work should be made immediately, to prevent counter preparations of the enemy.

After the repulse of an attack, all damages must be rapidly repaired, ammunition, &c., replenished, and the garrison should be strengthened, but not relieved, by fresh troops; the outer reserves would assume the offensive to complete the enemy's defeat.

In attacking and defending posts other than earthen redoubts, the same general rules apply; but there is generally more work for special troops in the shape of demolitions, and of making walls, &c., defensible.

Hasty Demolitions (Plate XXXVIII.).

410. Hasty demolitions in the field are usually effected by either gun-cotton or gunpowder: the former being specially carried for the purpose.

Gun-cotton is about four times as powerful, weight for weight, as gunpowder when not tamped; but in positions where charges of the latter explosive can be well tamped,† gun-cotton is about $2\frac{1}{2}$ times as powerful.

* The Land Service hand grenade is a small spherical shell weighing 1 lb. 14 oz. It can be thrown by hand about 30 or 35 yards.

† *Tamping* is covering the charge over with earth or other material, so as to confine the gases at the commencement of the explosion, and thus more fully develop their force in the intended direction.

The proportions of gun-cotton, and the sizes of the discs and slabs in which it is made up for use, are given in Arts. 6, 7, and 8.

Explosion is ensured by means of various kinds of detonators, fired either by simple fuses or by electrical machines.

Bickford's fuse and the detonator used in connection with it are those in ordinary use and are here described.

411. Bickford's Fuse is of two kinds—(1) Ordinary; (2) Instantaneous.

Ordinary Bickford's Fuse consists of a train of gunpowder enclosed in two coatings of jute thread twisted in opposite directions, and further waterproofed and strengthened by layers of tapes, gutta-percha, &c., according to the nature of the service for which it is required.

It is constructed to burn at a rate not exceeding 4 feet per minute, and its usual rate is about 3 feet per minute. It is best lighted with a vesuvian.

412. *Bickford's instantaneous fuse* consists of a strand of quick-match enclosed in several layers of gutta-percha and waterproofed tape: it burns at the rate of about 30 yards per second, and is quite water and damp proof, resisting prolonged immersion in water.

It may be known from the ordinary Bickford's fuse by its being coated with an open crossed snaking of orange-coloured worsted.

This fuse can be joined by baring short lengths of the quick-match, twisting the bared quick-matches together, and wrapping round with paper, tape, india-rubber solution, &c., or whatever may be available to make a waterproof joint.

413. In firing charges with the instantaneous fuse, a piece of the ordinary Bickford's fuse should be used in conjunction with it, in order to give time to get away from the effects of the explosion.

In making the joint, the quick-match of the instantaneous fuse should be bared for about an inch by cutting it on the slant, as in Fig. 319. The ordinary Bickford's fuse is treated in a similar manner, care being taken that the powder does not fall out. The ends thus cut are then jointed together, a little additional powder being added, if at hand, and the whole bound round with spun-yarn or tape.

414. When it is required to fire two or more charges simultaneously, and electricity is not available for the purpose, it may practically be done, as shown in Fig. 322, by using equal lengths of instantaneous fuse (bends being introduced, when necessary, to equalize the distance from the charges to the firing point) to be ignited simultaneously by a piece of ordinary Bickford's fuse. The joint is best made by baring the quick-match of the instantaneous fuse, as already described, and inserting the bared ends as well as the end of the piece of ordinary fuse into a small bag filled with sufficient powder to ignite them.

415. *Powder Hose* is sometimes used, in the absence of Bickford's fuse, for firing charges of gunpowder.

It is made of strips of strong linen sewn together, and is usually from ½ in. to 1 in. in diameter. It is made in lengths of 10 to 20 feet for convenience of filling (by means of a funnel), the lengths being afterwards connected together.

It burns at the rate of from 10 to 20 feet per second.

416. *The Detonator used with Bickford's fuse* is shown in section in Fig. 318. It consists of a copper tube, painted red, containing at the end A the fulminating composition: above this there is a wooden plug with a hole through it, in which a piece of quick-match is placed to communicate the fire from the Bickford's fuse to the fulminate. In using the detonator, the Bickford's fuse is cut to the required length, on the slant as described in Art. 413, and inserted into the hollow end of the tube, especial care being taken to push it down so as to rest on the piece of quick-match: the tube is then slightly bent so as to prevent the fuse from being withdrawn.

417. *Precautions in Firing Gun-Cotton.*—The primer should be thoroughly dry.

The charge should be in *close contact* with the object to be demolished.

The Bickford's fuse should be inserted well home into the tube of the detonator, and secured there (Art. 416).

In placing the detonator in the charge it should be inserted as far as point A (Fig. 318), so that all the fulminate is in contact with the gun-cotton.

On no account is the point of the detonator to be screwed or forced into the hole in the gun-cotton. The *rectifier* should be used to enlarge the hole when it is too small, care being taken that the detonator is not so loosely fixed in the charge as to be easily knocked out.

The lighted end of the Bickford's fuse should be directed and secured away from the charge, when the latter is untamped, so that there may be no danger of a spark setting the gun-cotton alight before the detonator is exploded. For this reason it is also advisable to cover the gun-cotton with a small quantity of earth.

418. *To blow down a tree with Gun-Cotton.*—Charge: 5 to 6 oz. for a tree 1 foot in diameter, and for other trees varying as the square of the diameter.

Thus for a tree 2 feet in diameter the charge will be $2^2 \times 6 = 24$ oz.

The charge should be placed in an auger hole bored horizontally into the tree at the desired height, as in Fig. 320.

When the tree is very large (over 18″ or 2 feet in diameter), two or more auger holes (as in Fig. 321) should be used. With a little care they can be bored to meet in the centre, in which case one detonator will suffice to fire the whole charge; but if there be no lack of detonators, it may be better to fire one hole first, and then bore a second hole in that part of the tree uninjured, and fire it; and so on until the tree falls.

The tree may be made to fall in any required direction by attaching a rope to the upper branches, and taking the strain on it before firing.

The discs $1\frac{3}{4}$ inches in diameter, used in a 2-inch auger hole, are the most suitable for this purpose.

When the gun-cotton is placed round the tree as a necklace, about eight times the quantity of that necessary in auger holes is required.

419. *Stockade.*—A single stockade of timber, 12″ × 12″, may be blown in by a charge of 3 lbs. of gun-cotton per foot run of breach. The slabs should be threaded together so as to be in contact, and hung or laid against the timbers at the required level (Fig. 327).

The slabs may be sewn to a thin deal plank for convenience of carrying and placing.

If gunpowder be used, a charge of 80 lbs. untamped, or of 60 lbs. tamped, with a few sand-bags piled on top of the charge, would be allowed for the same stockade.

This would probably make a breach 6 feet wide.

A stockade of 14″ timbers may be breached by 100 lbs. of gunpowder uncovered.

For double stockades the charge should be largely increased.

420. *To blow in a Gate.*—50 lbs. of gun-cotton, hung against the gate by means of a sharpened pickaxe, or laid on the ground as in Figs. 328, 329, will suffice.

The charge of gunpowder should be 200 lbs., covered with sand-bags if possible.

Precautions to be taken.—In work of this nature, every precaution should be taken against failure by protecting the men, either by sap shields or iron or other mantlets, which can be wheeled in front of them as a protection from fire; by having spare men detailed to carry the various stores, in case of accident to those first told off for the purpose, and by seeing that every man is provided with the means of firing the charge.*

* "It should be distinctly explained to men carrying tools, bags of powder, ladders, &c., that they are required to show their gallantry and steadiness, not in the use of their arms, but in the very important services to be rendered by the implements they carry."—*Instruction in Military Engineering, School of Military Engineering, Chatham.*

421. *To blow down a wall with Gun Cotton.*—With gun cotton the charge in lbs. $= \frac{1}{2} T^2 \times L$, where T = thickness of wall in feet, and L = length to be blown down in feet: the charge being equally distributed along the foot of the wall, and not tamped.

When tamping equal to the thickness of wall (as in Fig. 330) is added, half the quantity obtained by the above rule will suffice, or, charge $= \frac{1}{4} T^2 \times L$.

With very thick walls, grooves should, if possible, be cut in the wall, as in Fig. 331, so as to reduce the amount of the charge necessary.

Walls blown down with Gunpowder.—Charges of 60 lbs. of gunpowder placed against the wall at intervals of about 5 feet, and weighted with sand-bags, will breach a 14-inch wall.

422. *To blow down a House.*—With moderately thick walls the rule given in Art. 421 may be adopted, the portions of the walls attacked being those between the windows; the charges being tamped, and placed inside the house for choice.

Where this method would involve too much time or labour, on account of the difficulty of getting earth for tamping, the charges may be placed outside; or one or two large charges may be placed inside and fired.

Forty or fifty lbs. of gunpowder in a central position will blow down a small dwelling-house.

423. *Wooden Bridge.*—The rules given for felling trees (Art. 418) may be applied to the demolition of the timbers of wooden bridges, the uprights of the piers being the best parts to attack.

Or the bridge may be set on fire by first heaping a pile of combustible materials in the middle; petroleum, paraffin, or other similar combustible being poured over the timbers to make them burn.

424. *Masonry Bridges.*—When the bridge consists of a single arch, as in Fig. 332, the haunches are the best points of attack, two trenches, as at *b* and *c*, being dug across the width of the roadway down to the back of the arch.

Where there is no time for this, the charge should be placed along the crown of the arch, as at *a*. The breach effected will, of course, not be so large as by the former method.

Charges.—With gun cotton, if placed either along the crown or haunches, and untamped, the charge in lbs. $= \frac{3}{4} T^2 \times L$, the letters having the same signification as in Art. 421.

When the charge is tamped, with a depth of earth equal to the thickness of the arch, charge $= \frac{1}{4} T^2 \times L$.

If the bridge has more than one arch, and the piers are high and thin, it is better to place the charge against a pier, as the fall of one pier will involve the destruction of two arches.

The charge should be slightly greater than for a wall of the same thickness, and should be $\frac{2}{3} T^2 \times L$ when untamped, and $\frac{1}{3} T^2 \times L$ when tamped, gun cotton being used.

425. *Iron Girder Bridges* may be destroyed by placing a charge beneath the supports, as at A (Fig. 333); or the girder itself may be destroyed by charges calculated from the following table:—

To Cut through a Foot wide Iron Plate of Thickness given.

Thickness of Plate.	Charge of Gun Cotton.	Thickness of Plate.	Charge of Gun Cotton.
¼ inch.	— lb. 2 oz.	1½ inch.	3 lb. 8 oz.
½ ,,	— ,, 6 ,,	2 ,,	6 ,, 3 ,,
¾ ,,	— ,, 14 ,,	3 ,,	14 ,, 8 ,,
1 ,,	1 ,, 5 ,,	4 ,,	25 ,, 0 ,,
1¼ ,,	2 ,, 6 ,,		

426. *To disable Railways.*—Railways should not be injured except by special order.

A railway may be temporarily disabled by removing one or two rails from both up and down lines. The outside rails of curves are best to select, as they are the most difficult to repair.

When there is not time to disconnect the rails, they may be cut by exploding the gun cotton against them. The charge should be placed against the web, half-way between two sleepers, as shown in Figs. 324, 325; 8 oz. of gun cotton will cut through rails up to 70 lb. to the yard in weight. For very heavy rails, such as those of first-class railways, it would be better to cut up a 2-lb. slab of gun cotton into three equal parts, each of which would make a charge sufficient to destroy the rail.

Bridges across cuttings may be blown down, or the steep sides of a deep cutting may be thrown in.

427. *To destroy a Railway.*—Remove the rolling stock. Take up the rails and carry them to the rear; or throw them into a deep pond or river; or, if there is time, heat and twist them.

The sleepers and station buildings should be burnt; the water tanks rendered useless; fuel stacks set on fire or removed; bridges blown down; tunnels blown in. It is better to blow in one long tunnel in several places, than several tunnels in only one place each. The charges should be applied to the haunches.

Ordinary rails are of two kinds, double-headed (Figs. 323 and 324) and flat-bottomed (Fig. 325). They are connected together by fish plates and bolts (Fig. 323).

To remove the rails, unscrew the nuts from the bolts of the fish plates with a spanner, if available; if not, with a substitute made of a screw bolt and two nuts as in Fig. 326. Then knock out the keys, or draw the spikes, according as the rail is double-headed or flat-bottomed.

To twist the rails, the sleepers should be made into heaps and set on fire, and the rails placed across them. When the latter become red hot, they can easily be bent into a V shape. It is, however, better to twist them, by inserting the point of a pickaxe at either end in one of the bolt holes, and bearing in opposite directions. Thus twisted they cannot be used unless rolled afresh.

428. A line of telegraph should not be injured without special orders. To disable a line, remove the instruments; then with fine wire bind together all the wires forming the line, first scraping them clean and bright.

To destroy a line of Telegraph, cut down the posts, cut the wires, break the insulators, and break or carry off the instruments and batteries.

To destroy Guns.—In all field and siege guns detonate a 1½ lb. slab of gun cotton on the outside, near the muzzle.

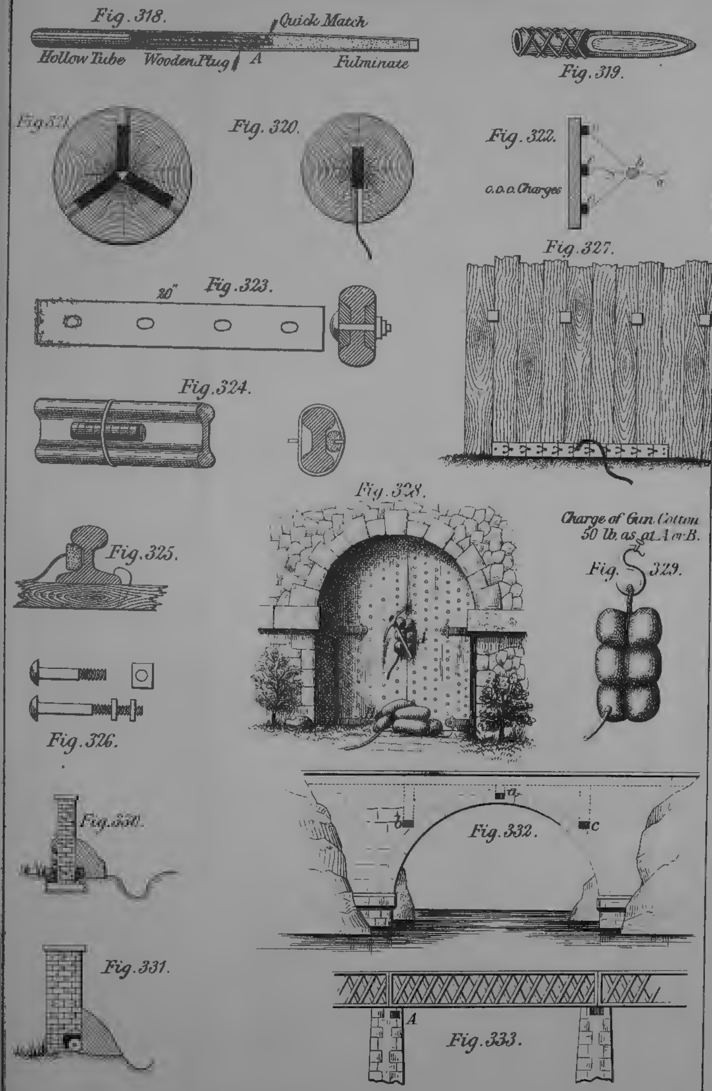
In heavier wrought-iron guns detonate 4 lbs. in the bottom of the bore, tamping with sand.

Heavy cast-iron guns can be burst by firing 1 lb. gun cotton in same position, tamping with sand.

ADDENDA TO CHAPTER IX.—EXAMPLES OF DEFENSIBLE POSTS, ETC., WAR OF 1870-1. (Plate XXXIX.)

429. Descriptions of some defensible posts that have been actually constructed, and in some instances attacked, during the late war, 1870-1, are here given, as they possess an interest—that of reality—which it is impossible to attach to simple theoretical types. As regards the posts round Paris, it should be borne in mind that the great number of villages, walled parks, châteaux, &c., combined with the large extent of wooded ground, gave the investing army extraordinary advantages of cover, with power to form any desirable extent of abatis, while the number and excellence of the roads prevented their lateral

HASTY DEMOLITIONS.



movements from being impeded. The French laws cause land to be very much subdivided, particularly when it is so valuable as about the villages near Paris; and the object of each owner of a plot seemed to be to wall himself in. These walls were thin, of soft stone, and easily loopholed, or notched at the top. For this reason it generally happened that the villages were bounded by rectangular enclosures, projecting more or less to the front, and often giving flanking, as well as fire to the front. The villages occupied by the French had the same advantages to resist an attack; but while sorties were obliged to take the offensive when their object was to break through, the investing forces could remain on the defensive, and so place their assailants at a disadvantage.

430. Investment of Paris. Fortified Post of Le Butard, near Versailles (Plate XXXIX., Fig. 334).—The farm buildings of "Le Butard" formed an important post on the left of the third line of investment, constructed by the 5th Prussian Corps d'Armée for the defence of Versailles against the sorties of the French army from the direction of Mont Valérien. They were situated on a main road leading from Versailles to the village of La Celle St. Cloud, and at the head of two valleys, the one running in a north-easterly direction towards the Seine at Bougival, the other nearly due east through Vaucresson and St. Cloud.

The post consisted of a farm-house, surrounded by an enclosure wall 10′ high, and a small ornamental two-storied building near it, which was favourably situated for flanking the approaches.

The farm-house itself was a low building, with high slate roof, and, except perhaps from the attic windows, fire from it could not be made use of.

The enclosure was loopholed on three sides, at about 7′ 6″ from the ground, a rough banquette of logs and earth being formed inside; and on the fourth side, which was unflanked (E F), there were two rows of loopholes, the upper ones being broken down from the top of the wall, and the lower tier at the level of the earthen banquette, or about 6′ above the level of the ground outside. These latter were intended for use by men lying down on the banquette slope: they were in the intervals between the upper ones. The iron gates in front of the farm were barricaded with a log parapet, the only entrance being through a small wicket gate.

Across the road, a very rough stockade had been constructed to flank the approach on the side most exposed to attack, and the whole of the woods which originally surrounded the post had been cut down, forming a vast entanglement and abatis about a hundred yards wide, and so thick as to be almost impassable.

The detached summer-house was well built in masonry, and stood on a projecting spur of the hill somewhat in rear of the farm. The windows had been barricaded, and a rough tambour constructed to cover the entrance, but it was not loopholed. The small enclosure wall round it, which carried an iron railing, was about 2′ high, and had been converted into a parapet, as shown in the section at A, B.

431. Investment of Metz. Village of Noisseville (Fig. 331).—This post, which formed a part of the line of investment on the south side of Metz, faced the French advanced post at Nouilley. The outlying walls, which were occupied, were particularly well suited for defence, as they afforded a fire to the front and flanks, and also flanked one another.

432. Investment of Paris. Village of Thiais (Fig. 330).—Thiais is on the south side of Paris, and formed part of the front line of investment. On its right was Choisy-le-Roi, a village on the left bank of the Seine, about half a mile distant, and on its left the line of investment was carried on towards Chevilly.

Thiais stands at the eastern shoulder of the plateau of Villejuif, the whole of which was well swept by the fire of a powerful French redoubt, Les Hautes Bruyères. Most of the village lies low, beneath the brow of the plateau, the crest of which is shown by the approximate contour line A, B, C. On the left of the village on the higher ground is a strong cemetery, round which a ditch was dug, and the earth piled up against the wall; the tombstones were used on the top of the wall, and in some places two rows of loopholes were obtained. The vaults and a field casemate gave good cover to the defenders. The enclosure walls of the village extended up to the edge of the plateau, and covered the infantry, while the fire from the cemetery flanked their front. Six gun-pits were thrown up to sweep the plateau: they were near the north-east corner of the walls, where the guns could be withdrawn by a lane into the village. On the extreme right were two breast-works of low profile; the smaller one was for guns, and flanked the slope of the plateau that looked eastward.

On the level open ground in rear of this village there were gun-pits for 24 guns, forming part of the second line of investment.

433. Chateau of Coeuilly (Fig. 333).—The garden of this château formed a salient point in the Prussian line of investment on the east and south-east sides of Paris, and commanded the road leading from Chennevières on the left to Villiers-le-Desert on the right, which runs in the valley in front. Beyond this road the ground rises to the front to the heights above Champigny (the scene of General Ducrot's great sortie), from which the enclosure of the garden could be seen into. It was very desirable, notwithstanding this defect, to occupy the garden owing to its favourable (salient) situation for flanking the ground to the right and left.

The enclosure wall was strong and 9′ high (section on C D); on the outside, the northern entrance had a short inner length of parapet on each side facing the entrance, which was covered by a strong traverse with a trench behind. To remedy the defect of the side walls being seen and enfiladed from the heights in front, great labour was spent in forming large traverses of trees and fascines (as shown in the sections), 24′ long and 12′ high. The western side was flanked by a battery of artillery posted at the edge of the Bois l'Abbé, while the hamlet outside the eastern side gave it flank defence, as did also the walls of the park, which extended eastward. The fruit trees on both sides of the garden were cut down and formed into abatis.

Very severe fighting took place on the high ground in front of this post; judging from the number of graves, in some of which more than one hundred men were buried, the loss of life must have been very considerable.

Fig. 334.

FARM OF LE BUTARD.

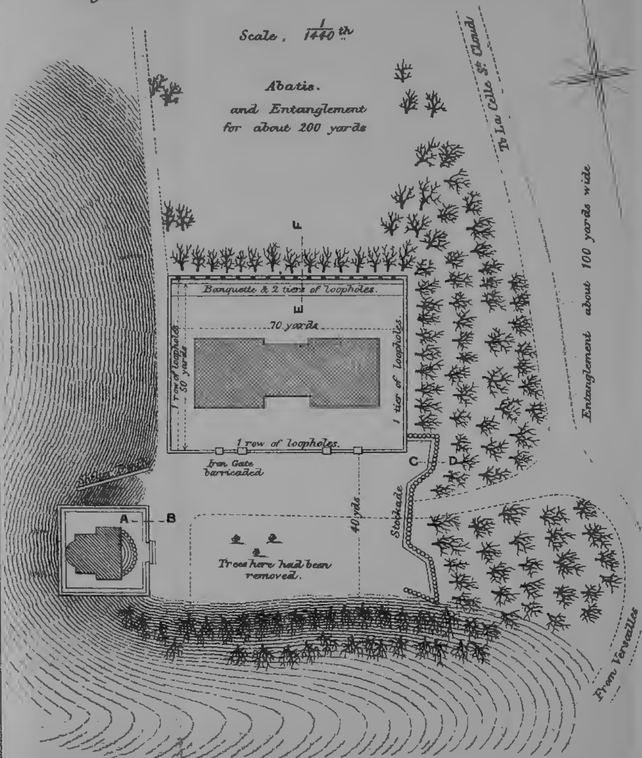


Fig. 335.

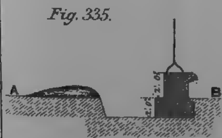


Fig. 336.

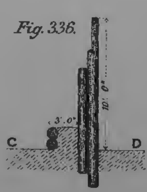
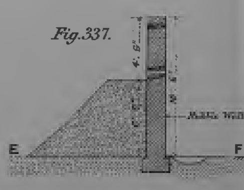
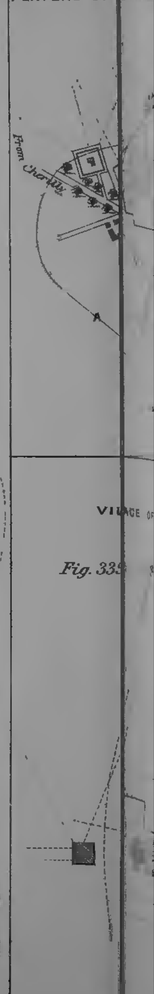


Fig. 337.





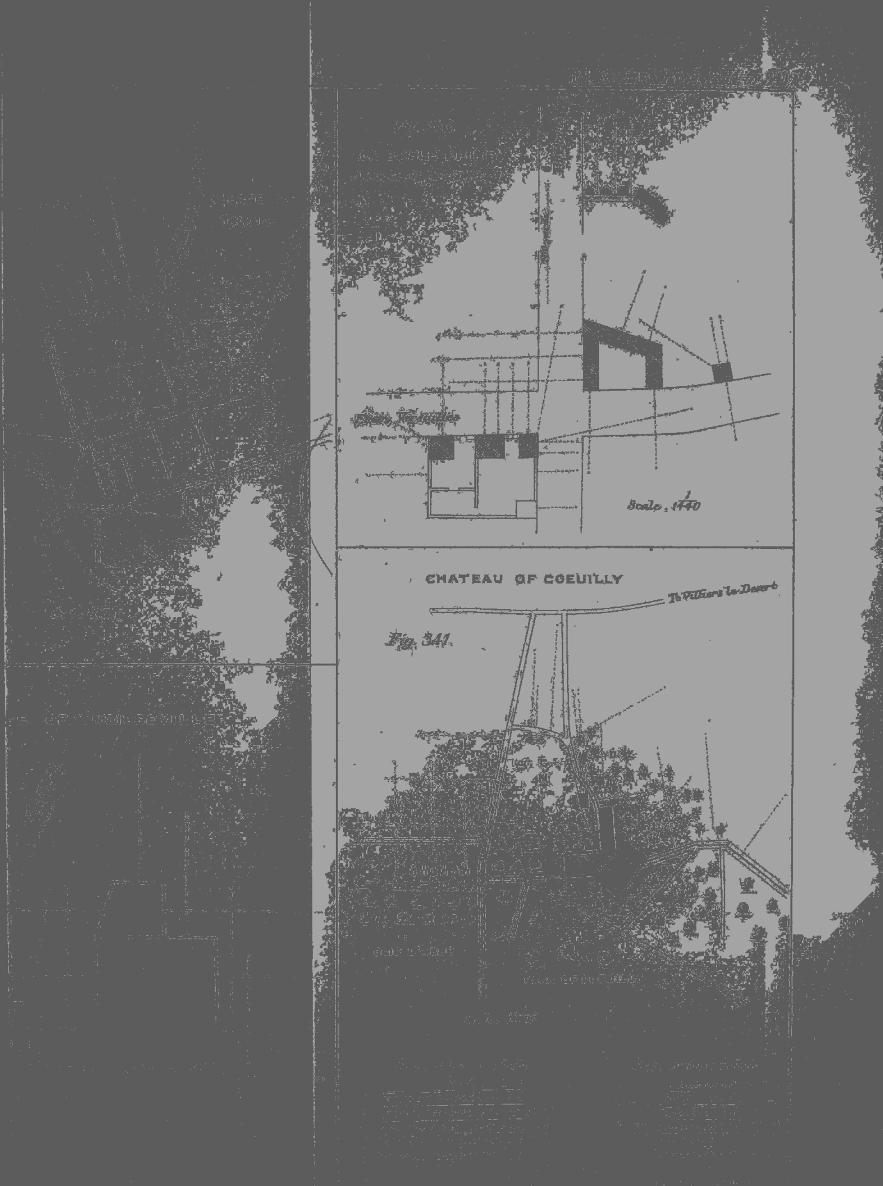


Fig. 341.

434. DATA FOR ESTIMATES OF THE ORDINARY ITEMS OF WORK REQUIRED IN HASTILY ENTRENCHED POSTS.

Nature of Work.	Arrangement of working Squads most usually suitable.	Amount of Work per Relief, not exceeding 6 hours' duration. Skilled Labour.	Unskilled Labour.	Tools, &c., for each Squad.	Remarks.
FELLING TREES.					
1. Scotch Firs, 1′ in diameter	2 men	36 trees	24 trees	1 felling axe..	Trimming branches takes about as long as felling. Cross cutting into lengths about half as long as felling small trees.
2. Hardwood trees, 1′ in diameter	2 "	24 "	10 "	1 " "	
3. Softwood trees, 2′ in diameter	4 "	..	20 "	2 " "	
ENTANGLEMENTS (Wood).					In 1 and 2, fell four rows of trees at the edge of wood, or where a cleared belt is to be made, interlacing the branches. With very large trees, cut down only the branches and underwood to form the entanglement. In 3 and 4, cut the rods half through, bending them towards the front to form the entanglement.
1. Fir trees, 1′ in diameter	10 men	100 yds.	About one-half of these quantities	5 axes, 3 fathoms 3″ rope	
2. Hardwood, 1′ in diameter	10 "	36 "		5 " 8 " 3″ "	
3. Underwood only ..	10 "	50 "		4 " 1 saw, 5 bill-hooks	
4. Copse	10 "	60 "		1 axe, 9 bill-hooks.. ..	
ENTANGLEMENTS (Wire). Materials at hand ..	12 men	..	100 yards	2 axes, 2 bill-hooks, 2 gabion knives for making 200 stakes, 2 mauls, 2 pairs pincers, 1,500 yds. wire	Stakes 3″ diameter, 4½′ long, in 4 rows, at 6 feet intervals.
LEVELLING EARTHEN BANKS.					
1. Bank averaging 5′ in height and 3′ thick, without hedge or trees growing on it ..	10 men	..	100 yards	10 shovels.	
2. Small bank, with hedge growing on it	10 "	..	80 yards	10 shovels, 2 picks, 2 bill-hooks, 2 pairs of gloves	From practice at R.M. College.
LOOPHOLING WALLS, Forming loopholes in 9″ brick wall	2 men, 1 working at a time	..	30 to 40 holes	1 pickaxe	Notching or crenellating the top of a wall takes less time than loopholing it, especially with thick walls.
Forming loopholes in 14″ brick wall..	2 men	..	30 to 40 "	1 pickaxe, 1 crowbar, short	
Forming loopholes in 24″ brick wall..	2 "	..	12 to 15 "	1 pickaxe, 1 crowbar, short	
CONVERTING BANKS AND HEDGES INTO PARAPETS. Banquettes formed, trenches dug, openings made to fire through, &c ..	10 men	..	60 to 200 yds. according to the work required.	8 shovels, 2 pickaxes 2 bill-hooks.. ..	This must always be a very variable item according to state of line to be converted. From practice at R. M. College 100 yards seems a fair average for ordinary cases.
SHELTER TRENCHES, 5′ × 1′ 6″.					
1. Ordinary soil	3 men	..	5 yds. per man	2 shovels, 1 pick.	
2. Difficult soil	2 "	..	4 " "	1 shovel, 1 pick.	
STOCKADES—Timber at hand.					
1. Very rough work ..	8 men	..	16 feet	2 picks, 2 shovels, 2 axes.	
2. Neat strong work..	8 "	16 feet	.. ..	Additional for No. 2—1 each cross cut and hand-saw, 2″ chisels, mallet, adze, 2 large gimlets, 24 (6″) spike nails, and 6 iron dogs.	
BARRICADING DOORS & WINDOWS roughly with sand-bags, or boxes, &c., filled with earth	8 men	..	4 or 5 windows, 2 doors.	1 pickaxe, 1 shovel, 1 crowbar (short), 1 handsaw	Windows of upper floors need only be built up to a height of 6½′ above the floor.
ABATIS—materials on the spot	10 men	..	20 yards.	5 axes, 5 bill-hooks, 2 saws, 2 mauls, 2 ropes	Three wagon-loads of branches required.
MILITARY PITS (Trous de loup)	Any suitable number: men working singly	..	2 large or 10 small pits per man.	1 pickaxe, 1 shovel per man. 1 maul, 1 axe, 1 bill-hook .. per squad.	
RIFLE PITS, detached ..	Do. do.	..	2 to 3 pits per man	1 pick, 1 shovel per man 4 sand bags per pit.	
GUN PITS	8 men	..	1 pit in 1 hour, 3 to 4 in a relief	8 picks, 8 shovels.	

N.B.—The amount of work to be expected in one relief is placed very low in this Table, in order to allow for the difficulties which attend the execution of works in a campaign, and also with the understanding that the troops who prepare a post for defence have also to defend it. Much more work may be expected when conditions are favourable, such as fine weather, men fresh for work, &c., &c.

CHAPTER X.

WORKS ADAPTED TO THE GROUND.

Nature of the subject; usual mode of proceeding in arranging a scheme of defence; limited extent of the subject treated in the present chapter. Manner in which the object of a work may influence its shape. Ground favourable for defence, or the reverse. Detail of the advantages of a position on rising ground. How to occupy the summit of a gentle slope with a work. Defect of slope which is convex in section. How to occupy the summit of a very steep, but not precipitous slope; also a slope which is precipitous. Useful practical problems.

EXAMPLES.—1. *A salient bend of a hill occupied by a salient angle.* 2. *A low spur of a hill occupied by a salient angle.* 3. *A redoubt occupying the summit of a hill.*

435. The formation of the ground selected for the site of intrenchments influences, to a considerable extent, both the trace and the profile of the works to be constructed. The trace of a work is frequently determined from the shape of the ground it occupies, and the command is greatly dependent on the slope of the ground, both in front and also inside, or in rear of the work.

The art of apportioning works for the defence of a given position, in such a manner that the objects of defence are attained with the smallest possible expenditure of time and labour, is the most difficult branch of the science of the Field Engineer. It requires for its fulfilment a practical acquaintance with the modes in which troops of all arms are manœuvred, in order that the works selected shall aid to the utmost the efforts of the defensive troops, and it also requires a good eye for ground, in order to be able to select such sites for the works as will give the greatest defensive advantages with the least labour.

The general scheme of defence for a position is arranged by the Commanding Royal Engineer (from instructions by the General in command), who would determine the number and sites of the proposed works, their general dimensions and armament, the position of troops to support the works, &c.; in fact, the mode of occupation of the position as a whole. The details of execution of any one work, the determination of its exact shape, and of the profiles of its various parts, &c., are important duties that may fall to the lot of an individual officer. The object of this chapter is to facilitate the comprehension of this practical and highly useful branch of Field Fortification.

436. A work of defence may sometimes be constructed rather for offensive than for defensive purposes—that is to say, its object may be more to bring a strong fire on a particular ground which would favour an enemy's attack, than to resist an assault. In the former case the work assumes the nature of a battery, being especially intended to afford protection to the guns that may be placed in it, and its outline cannot be too simple; but when the object of the work is purely defensive, as is the case when it is intended to prevent an enemy occupying the ground on which it stands, the work should be planned so as to be capable of resisting a powerful assault, and every attempt should be made to increase its defensive powers by giving it a strong profile, by providing a good flank defence, and by making use of all the accessories of defence, in the shape of obstacles, &c., that have been already described.

In many cases a work may be required to fulfil both conditions, for it may be in a position favourable for the action of artillery for offensive purposes, while it may also be an important point to hold in respect to the general defence.

437. The most favourable situation to occupy for defence, whether with or without works, is the top of rising ground which has a gentle slope before it, like a glacis, that can be grazed by the fire of the defenders; at the same time the upper surface of the ground should be level, or, still better, should have a slight fall to the rear, so as to conceal the ground in rear of the position from the view of an enemy, thereby masking the movements of the defensive troops. The position should not be commanded, within range, by heights which could be occupied by an assailant.

Very high ground is not necessarily good for defence, as the fire from it becomes too plunging* to be effective, particularly at night, and against troops in motion; and if the slopes be very steep, they cannot be swept by the frontal fire of the works; while, on the other hand, they can be surmounted by an assailant unless they are so steep as to be precipitous.

Works frequently have to be constructed on ground unfavourable for defence; as, for instance, when the site occupied is commanded within effective range,† or when the face and not the summit of a hill is the site of the work. In either case increased height of parapet is necessary, in order to afford cover for even a short distance in rear; while, in the latter case, difficulty would be experienced in draining the work, which from its position would intercept the water running down the face of the hill.

438. A position on the summit of rising ground, occupied to resist an attack, combines the following advantages to a greater or less extent, according to the actual shape and slopes of the ground, both in front and in rear of the position.

The ground in front is overlooked by the defenders, owing to their elevated position.

The movements of the assailants, the strength and position of their reserves and of their artillery, will thus be made known to the defenders, unless concealed by accidental circumstances, such as the existence of woods, &c.

The group in rear is concealed from the enemy's view.

The reserves of the defenders can therefore be posted in situations unseen from the front, while changes in their position may be effected to meet the varying requirements of the defence, also screened from the view of the enemy, who will thus be unable to determine, from actual observation, either the strength or position of the defenders.

The front slopes of the position up which the enemy must advance to the attack can be defended by a grazing fire, the most effective that can be employed against troops in motion.

These advantages result from a good choice of situation, and are independent of intrenchments; they will, however, be augmented should the position be strengthened by field works.

439. When a line of work occupies the summit of a gentle slope, it should be retired sufficiently from the crest of the hill to enable its musketry to defend the slope. This may be considered as effected if the fire can be directed within 3 feet of the surface of the ground. Considerable latitude in the choice of the actual position of a line of parapet on favourable ground will thus be allowed; for instance, a line of work occupying the summit H in Fig. 342, Plate XL., might have its crest at *a* in the line of fire *a b*, or at *c* in the line of fire *c d*, each passing within 3 feet of the surface of the slope, and therefore properly defending it; or the crest of the parapet might occupy any intermediate position between these two lines, and be equally efficient for defence.

The line *a b* is here supposed to pass 3′ above the foot of the slope, and close to (almost graze) its crest.

The line *c d* may be assumed as passing 3′ above the top of the general slope. The points *a* and *c* may be termed the *most retired* and the *most advanced* positions suitable for the parapet.

440. When a line of work occupies rising ground, the slope of which forms a decidedly convex curve in section, it will frequently be impossible to defend

* Plunging fire is comparatively ineffective against troops when they are *uncovered* and *in motion* on open ground. It is, however, the most effective fire that can be brought to bear upon troops *when posted behind cover*, as in the trenches and batteries at a siege, because the cover afforded by any parapet evidently diminishes as the fire against it becomes plunging.

† This is very frequently the case with the works composing Bridge Heads.

the entire surface of the slope, if the work occupies the highest part of the ground, as at A, Fig. 343. To obtain such a defence for the ground in front it would be necessary to advance the position of the parapet as shown at B, whence its fire can evidently graze the slope; but this advantage is obtained in this case by occupying an unfavourable position for the work, which would require a high parapet on account of the ground rising behind it, and the work would, moreover, be difficult to drain. But notwithstanding these disadvantages, portions of works must frequently occupy situations similar to B.

If the parapet were constructed at A, Fig. 343, direct defence for the ground in front could only be completely obtained by paring the surface sufficiently to allow the musketry fire to be brought within 3 feet of it; but this operation would entail more labour than could usually be devoted to the purpose.

It will, however, frequently happen, after having resorted to every practicable expedient, that there will remain some ground in front of a work which cannot be defended by a frontal fire. When such is the case, endeavours should be made to obtain a flank defence for it, and to obstruct, as much as is practicable, the approach of an assailant in that direction.

441. The defence of a slope of ground becomes less favourable as the slope increases in steepness, because the defensive fire requires greater depression to defend the slope; the superior slopes of the parapets require, consequently, to be made steeper, and the parapets are thereby weakened. There is also less choice of position for the parapets, as is illustrated further on.

When the slope of ground is so steep as to prevent its being properly defended from a parapet, and yet not sufficiently steep to be inaccessible to an assailant, it is not usual* to occnpy the crest of the slope with works, but to retire them some distance, as in Fig. 344; for by so doing the ground in the immediate front of the works is well defended, and an enemy would have to pass over it after being disordered by the ascent of the slope, which should *be flanked from convenient points*, so as to ensure an enemy being seen while mounting it.

442. When ground occupied for defence is so steep as to be inaccessible to an enemy (which is a case of rare occurrence for any considerable extent), the crest of the slope may be occupied by works which would possess the advantages resulting from a commanding position without the obligation of defending the ground immediately in front. The steep ground should, if necessary, be made steeper by *scarping*, as shown by the dotted lines in Fig. 345, so as to form an insurmountable obstacle to an assault. A site of this kind forms an admirable position for artillery to assist in the defence.

443. When works are constructed on the top of rising ground, each separate line of parapet will usually be situated, as shown in Fig. 346, in one of three positions with reference to the slope of ground in its front, which it has to defend by its fire.

1. As at A B, where it is in rear of a straight line of slope. In this case all the choice of position shown in Fig. 342 will exist, and it must be evident that the line of parapet A B need not be parallel to the line of slope.

2. Or, as at B C, where it has a salient bend of ground in front. Here, the ends of the parapet B and C will be closer to the slope than the centre x, which latter point will represent the retired position shown at a, Fig. 342, while B and C correspond to the advanced position shown at c in the same Fig.

3. Or, as at C D, where it has a re-entering slope in front. In this case the ends of the parapet C and D evidently correspond to the retired position a, Fig. 342, while the centre y corresponds to the advanced position c.

444. The following simple practical operations require to be constantly carried out when tracing works on high ground.

* This refers to regular parapets only, for good musketry cover can be provided for infantry to defend a slope, however steep it may be, provided that it is not precipitous, as shown in Fig. 344 by the dotted profile.

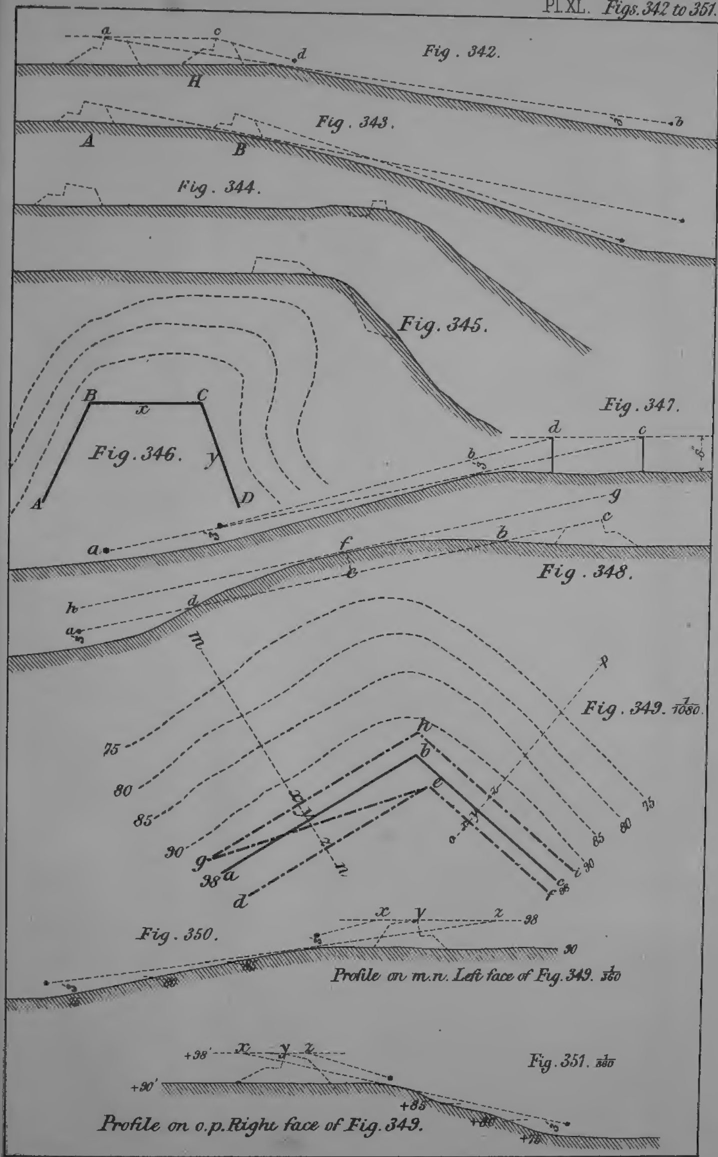


Fig. 342.
Fig. 343.
Fig. 344.
Fig. 345.
Fig. 346.
Fig. 347.
Fig. 348.
Fig. 349. 1/1080
Fig. 350.
Profile on m.n. Left face of Fig. 349. 1/360
Fig. 351. 1/360
Profile on o.p. Right face of Fig. 349.

To determine the most retired position for a line of parapet of given command to defend a given slope.

The observer should look from the point *a*, Fig. 347, 3′ above the ground at the foot of the slope, to the crest of the hill. An assistant should move an upright rod, of the height of the intended parapet, backwards or forwards, until its top comes in the line of sight of the observer, as at *c*, which thus marks the position of the crest at one particular point. A similar observation should be made at some other point in the required line of parapet.

To determine the most advanced position for a line of parapet of given command to defend a given slope.

Here the observer at *a*, Fig. 347, 3′ above the ground, should look in the line *a b* parallel to and 3′ above the slope, by means of an assistant, who fixes the point *b*. The upright rod, when brought into the position *d*, where its top coincides with the line *a b*, fixes the position of the crest. The operation should be repeated at other points in the parapet.

If the slope of ground be very gentle, this operation is unnecessary, as the superior slope of the parapet may be steeper than the ground in its front. The parapet may be advanced sufficiently to allow its superior slope produced to pass 3′ above the ground *at the top of the slope*, as *c d* in Fig. 342.

N.B.—If the observer stand on the top of the hill so as to place his eye in the prolongation of the general surface of the slope, then his position will mark, sufficiently correctly for many practical purposes, a point in the crest line of a parapet of ordinary height ($7\frac{1}{2}'$ or 8′).

To determine the amount of ground to be cut away so as to allow the fire of a parapet to defend the foot of a given slope in its front.

The position A, Fig. 343, illustrates the use of this problem. In this case the foot of the slope is undefended by the parapet at A, which position combines the maximum command, or rather height of situation, with good cover in rear.

In Fig. 348 the defect is exaggerated to explain the problem.

The fire of the parapet, passing from the crest *c*, is required to reach *a*, 3′ above the ground at the foot of the slope. The line *c a* cuts the surface at *b* and *d*, and the vertical line *f e* represents the greatest depth at which it passes under the surface.

It is first necessary to find the line *g h* parallel to *c a* and tangent to the hill. This is effected by raising up marks of equal height, say 6 inches at a time, above the points *c* and *a*, until by trial the mark at *g* becomes just visible from *h*. Then the depth *f e* is the same as *a h* or *g c*. The dimensions of these lines can be obtained correct to one inch with great ease.

The points *b* and *d* may be found by moving a rod of the length of *g c* or *h a* along the ground in a vertical position, until its top coincides with the observed line *g h*; when this is effected it will be resting on the required point.

Three examples are here given to illustrate the foregoing remarks; in each case it is assumed that the musketry fire of the work (or its superior slope produced) must be able to pass within 3 feet of the surface of the ground, and that the parapets are 8 feet in height, unless otherwise specified.

445. A salient angle is required to occupy the ground, shown in Fig. 349 by the contour lines.

Two faces, *a b* and *b c*, are here shown, each parallel to the general line of the slope in their front, and sufficiently retired from its crest to be able to *graze* the slope by their musketry fire.

This will be evident from an inspection of the profiles, Figs. 350, 351.

The trace here given might be considerably modified: the faces might be retired as far as the lines *d e* and *e f* if a smaller work were required, or they might be advanced as far as the lines *g h* and *h i* if a larger work were desirable, without affecting the efficiency of the direct defence of the ground in front of the work. Again, if the direction of the line of parapet *a b* were not suitable for the fire required from it, it might be made to occupy any position most advantageous between g h and d e, as, for instance, g e or d h, without affecting the proper defence of the slope in front.

This example illustrates a very favourable case; for as the work is situated on level ground at the top of a moderate slope, it can be easily adapted in outline so as either to suit the shape of the ground, to bring a fire into a required direction, or to receive flank defence from collateral works.

446. In Fig. 352, Plate XLI., a less favourable case is illustrated. In this instance a low spur of a hill is occupied with a redan as an advanced work, from which a flank fire can be brought to bear on the slopes of the hill.

The slopes of the spur in front of the redan, *a*, *b*, *c*, are not perfectly defended by the fire of its faces, as will be seen from the profiles given in Figs. 353, 354.

This would be better effected if the faces of the work were retired further back; but then a fresh defect would be the result, owing to the rapid rise of the ground in the interior of the redan, which would render it difficult to obtain proper cover in the work.

Notwithstanding these inconveniences, a position similar to that shown may frequently be occupied with an advanced work, either for the purpose of flanking the slopes of the main hill, or to see into ground otherwise hidden from view. The ground in its front should be defended by a cross fire from the main position in rear, from which also a view of its interior should be obtained, as in Fig. 196, Plate XXI.

A principal difficulty attending the maintenance of a work in such a position would be its drainage. As its salient occupies lower ground than its gorge, it would be necessary to make drains leading under its salient into the ditch. Too much care can hardly be bestowed on this important point, if the work be liable to be occupied for any considerable time.

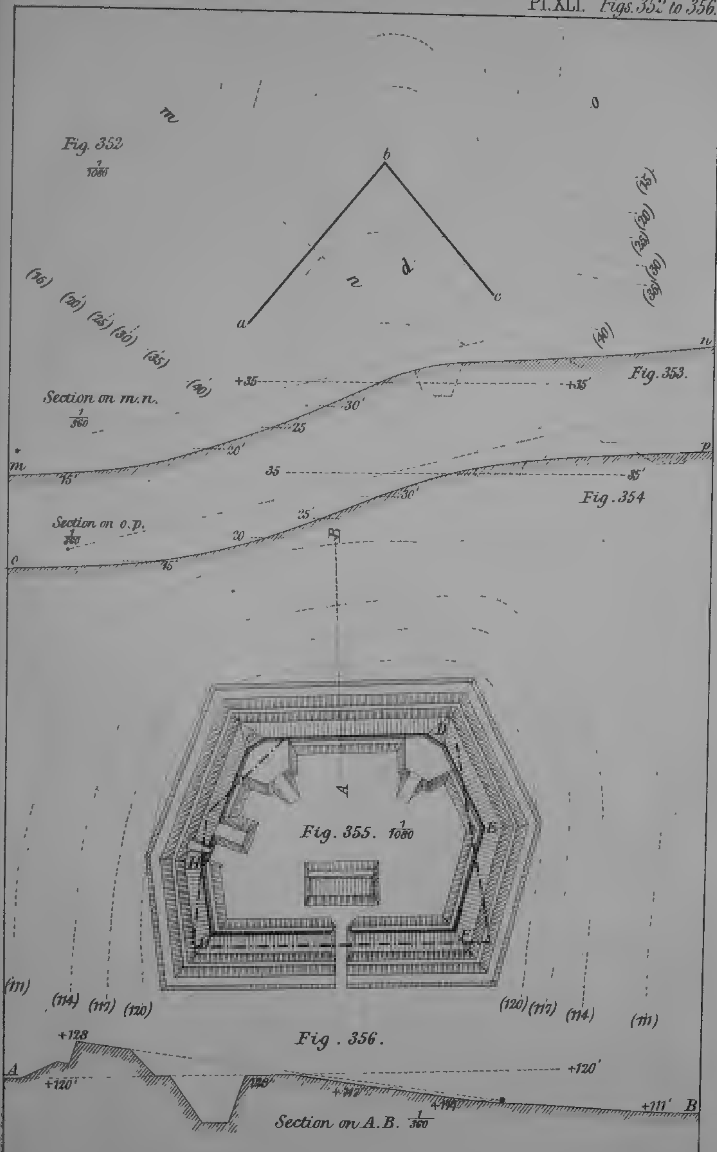
447. Fig. 355 is an example of a hill, the summit of which is occupied by a redoubt.

It is here supposed that the entrance opening is placed on the rear of the work G F; that the three *front* faces, H C, C D, and D E, are properly traced, *as regards their direction*, for bringing a fire on to ground most requiring it; and that the remaining faces, H G and E F, are long enough to afford sufficient interior space to the redoubt, or to fulfil any other requirement. Such being the case, the work shown is well adapted to its intended object, for it fulfils the two important points of *being able to bring a fire into the required directions*, and of *suiting the shape of the site on which it is constructed.*

The profile of the front face on the line A B, Fig. 356, shows that the slopes of the hill are well defended by the fire from the work.

The outline of the redoubt might be considerably altered from that shown in Fig. 355, without losing the advantage of being able to defend the slopes of the hill, if the requirements of the work demanded a different direction to any of the faces. For instance, the trace shown by the thick dotted line would be good, so far as regards its suiting the shape of the ground.

Pl. XLI. Figs. 352 to 356.



be chosen, so as to avoid confusion, and allow of proper direction by the General in command.

The columns must be covered and supported by skirmishers, but must themselves advance rapidly without firing. No one must be allowed to fall out, to take to the rear wounded officers or men; the wounded must find their own way back, or wait for the stretcher party.

451. Each column will usually be headed by an *engineer party*, to open a road through the palisades of the covered way or other obstacles; and along with this there will be a *carrying party*, with bags of hay, planks, hurdles, or fascines, to help the troops to cross, or to jump into, pits or ditches.

The *advance of the storming party* should follow about 30 paces behind the carrying party, and the same distance in front of the *support* or *main body*.

The *reserve* should be about 100 paces behind the main body; and this again will be followed (or sometimes preceded) by a working party, to form a lodgment if the work is to be held, or to dismantle it if it is to be abandoned.

There should also be an *artillery party* immediately in rear of the main body, to serve any guns that may be taken, or to spike them in case of a repulse.

In rear of the working party follows a *stretcher party*, for the removal of the wounded.

452. If there are works to be escaladed, *ladder parties* will be attached to the advance, and to the supports of the storming parties.

The advance, with the first line of ladders, after descending into the ditch, move their ladders across the ditch, ascend the escarp, form on the berm, fix bayonets, and rush over the parapet in a body at a signal from the Commander.

The support, with the second line of ladders, should reach the counterscarp as the first line is crossing the ditch: they lower their ladders into the place from which the first line has been removed, and after descending leave their ladders there, so as to establish a continuous line of communication for the working party, reserve, &c.

There should be ladders enough for an assault on a broad front (30 or 40 men). At least 3 feet of the head of each ladder should be above the wall against which it is placed, to assist the men in getting on and off.

An escalade is hardly practicable if any of the walls to be ascended or descended are more than 30 feet high, because of the weight of the ladders required, and the difficulty of carrying them. Ten men will be required to carry a 36-feet ladder, which will be wanted for a 30-feet wall. As the attempt can hardly succeed except by surprise, it must usually be made at night; and therefore the troops should be practised beforehand, by night, in escalading drill, as any noise, confusion, or delay might be fatal.

453. The strength of the several portions of an assaulting column must depend on circumstances; but the importance of using large numbers has been repeatedly shown (*e.g.*, Badajoz and Sebastopol). "The miserable, doubting, unmilitary policy of small storming parties, on the plea that *if we fail we can't lose many men*, causes more mischief, loss, and disgrace than any other proceeding in war."—(Sir J. Burgoyne.)

An assault, if successful, has the advantage of being a rapid undertaking, not requiring a siege train, whereby much time is gained: the loss experienced, although probably heavy for a single operation, would not outweigh that which would necessarily be incurred in carrying on a siege.

454. A BOMBARDMENT is an attempt to overwhelm a place by throwing into it a great quantity of shells, rockets, &c., from batteries of guns and howitzers, with the object of burning and destroying the town (not the fortifications), and forcing, by means of the pressure put on the governor by the inhabitants, the surrender of the place, without the attacking force having to go through the more tedious operations of a siege.

The object of a bombardment may be, as at Sweaborg in 1855, merely to destroy naval or military stores, arsenals, and ships.

This method of attack is undertaken when the assailants are unprovided with the means, or cannot spare the time, for a siege, and when the fortress is insufficiently provided with bomb-proof cover. Against a well-constructed fortress it would be ineffective, as the garrisons are protected by being lodged in bomb-proof buildings, and suffer but little from the effects of high angle fire, which falls principally on the inhabitants. It might succeed (and often has succeeded) against a small place unprovided with bomb-proof cover; or where the governor is a weak man, whose sense of duty yields to his feelings of humanity; or where the garrison is insufficient to keep the inhabitants in subjection under the miseries inflicted on them.*

455. Blockade.—To blockade a place is to *invest* or to surround it with superior forces, sufficient in number to prevent any communication between the garrison and the country until a surrender becomes unavoidable from want of provisions. It is, in other words, an attempt to starve out a given garrison.

Its success will depend on the vigour with which the investment is maintained, and on the time the garrison can hold out before they can be relieved.

Partial bombardment may be resorted to in order to quicken a surrender.

A blockade is usually undertaken by an army unable to attack a fortress in any other way, either by assault, by bombardment, or by regular siege, as its duration is greater than that of any of these methods of attack.

A fortress while being besieged should always be blockaded (or, as it is termed, *invested*), in order to confine its garrison and inhabitants to existing resources of ammunition and food, and to prevent reinforcements being furnished to the garrison, and the sick and wounded being got rid of.

456. Regular Siege or Systematic Attack is the most certain, the best, and most usual method of attacking a fortress properly constructed and efficiently garrisoned, *provided that the besieger is in a position, as regards resources in men and material, to carry it on with vigour.* But when a siege is attempted without sufficient means, experience has shown that no operation of war is more difficult of success, or more disastrous in its effects if unsuccessful.

In a regularly conducted siege, a fortress is first thoroughly invested by superior forces, so disposed in the environs as to confine the garrison to the immediate vicinity of their works, and to exclude any supplies from without of men and warlike material. After this has been effected, the besiegers determine the most favourable side of the fortress to be attacked: they then construct batteries for guns and howitzers, to silence or keep under the fire of the works of the fortress in their front, protecting such batteries from the attacks (sorties) of the garrison by keeping a sufficient force in their neighbourhood, under cover in trenches made for the purpose. Approaches by means of open trenches disposed so as to avoid enfilade, other trenches for the protection of the guards, and further batteries are now made; and, in time, the besieger is able to batter down the escarp wall, and to carry his trenches up to the foot of the breach. The besiegers' troops being thus enabled to march in security to the breach made in the walls of the town, can assault it, being in general superior in numbers to the garrison defending it; and as they (the assailants) are assisted by a fire of artillery and musketry directed on to the defenders of the breach, which fire can be maintained, without injury to the assailants, until the very moment of personal contention, the breach, if properly attacked, is generally carried; and this leads, in all probability, to the capture of the place.

457. Troops and Armament for the Attack of a Fortress.

Strength of a Besieging Army.—The strength of the Siege Corps will depend on the nature and size of the fortress to be attacked, and on its garrison. The Siege Corps should be sufficiently strong—

(1.) To invest the fortress completely, and to maintain the investment against all the efforts of the garrison.

* Sixteen French fortresses surrendered to bombardment in 1870; among them were Toul, Thionville, Verdun, Mézières, Neuf-Brisach, Longwy, Peronne, &c. Strasbourg successfully resisted a bombardment and had to be besieged.

(2.) To execute and guard all the requisite siege works.

In addition to the besieging troops, an army of observation will generally be required to prevent the enemy's troops in the field breaking the investment and relieving the place; also to frustrate any attempt to raise the siege.

In general terms, a force twice that of the garrison is required to invest it closely, and one of from three to four times its strength is required to prosecute a siege actively. As the garrison of a place increases, the *proportionate* strength of a besieging army will decrease, although its *actual* strength will, of course, increase.

But such general estimates must be largely modified to meet particular cases; and, like all other operations, Sieges may have to be undertaken, and may be brought to a successful termination, by forces much below the strength that safe estimates would give.

458. As an example of the calculation for a Siege Corps, the small fortress shown in Plate XLII. may be taken as being garrisoned by 5,000 men.

The line of investment of such a place would be about 12 miles long. Three detachments, each about two-thirds of the strength of the garrison, could probably maintain this line strictly from the first, and afford each other support if attacked. By the time the regular siege began, the investment line would have been fortified, and could be held by fewer men. Two of the detachments might then be reduced to one-half the strength of the garrison—2,500 men each. The third detachment, on the side of the intended attack, might be raised to 7,500, to furnish guards of the trenches, at *three reliefs*, equal to *half the strength of the garrison* (this being considered as the greatest number that could be collected together for a sortie).

The *working parties* necessary for carrying on the siege works will vary in number at different times, more being required in the early periods of the attack than towards the end, but as an average they may be taken as 2,000 men, and they should be in four reliefs.*

The total strength of Siege Corps for a garrison of 5,000 men will thus be—

Investing troops on side not attacked	2 × 2,500 = 5,000
Guards of Trenches, half the garrison in 3 reliefs...	3 × 2,500 = 7,500
Working parties, 4 reliefs	4 × 2,000 = 8,000
Total	20,500

or *four* times the strength of the garrison.

459. With a large fortress, surrounded by detached forts, and garrisoned by 40,000 men, the line of investment would be about 30 miles in length (*e.g.*, Metz). An army of 80,000 men would allow about 2,700 per mile, and this would probably be no more than sufficient *at first* to resist the sorties of so large a garrison.

Although the length of the investment line does not increase in proportion to the increase of the garrison, the greater number of men per mile required to guard it will keep the total of the investing force at something like a constant ratio of 2 to 1 to the garrison, unless the latter be out of all due proportion to the extent of the place.

The additional troops required for a regular siege become, however, proportionately fewer as the garrison increases.

For the simultaneous attack of three detached forts the working parties may be estimated at 1,500 men per fort, in 4 reliefs.

For the Guards of the Trenches 3,000 men per mile would probably suffice. This at 3 reliefs upon a front of four or five miles would require 30,000 men, one-half of whom might be drawn from the investing troops.

* The German rule during the war of 1870—71 was that the maximum effort required of each man should be one day's outpost duty, and the next day with working party, followed by rest on the third day.

On these data the total strength of the Siege Corps to attack a garrison of 40,000 men will thus be—

Investing troops on side not attacked	60,000 men.
Guards of trenches, 4½ miles at 3,000 per mile in 3 reliefs, say	40,000 ,,
Working parties, 1,500 men per fort, for 3 forts, in 4 reliefs	18,000 ,,
Total	118,000 ,,

or (about) *three* times the strength of the garrison.*

From the above it may be deduced, as before stated, that a Siege Corps should as a rule be 3 or 4 to 1 to the garrison, according to the size of the fortress.

The composition of the Siege Corps should be adapted to its special work. The proportion of Cavalry may be less than with a field army, but the proportion of Artillery and Engineers must be largely increased. The number of "Garrison Batteries" should be about one-fourth of the largest number of siege guns and howitzers that are likely to be engaged at any one time, so as to allow 30 men per gun, or three reliefs of 10 men each. The Engineers should not be less than one-twentieth of the strength of the infantry, and considerably more, if possible. There should be from 20 to 40 additional engineer officers.

460. Siege Train.—The siege train in the British Service is organized by units of 30 pieces of rifled ordnance each: there are a *heavy* unit and a *light* unit.

The heavy unit consists at present of—

Eight 64-Prs.	of 64 cwt.
Eight 40 ,, ...	35 ,,
Fourteen 8″ Howitzers	47 ,,

The light unit consists of—

Ten 40-Prs.	of 35 cwt.
Ten 25 ,, ...	18 ,,
Ten 6·3″ Howitzers	18 ,,

With each of these units are associated six 7-Pr. Guns to be mounted on beds for high angle fire at short ranges, and 300 24-Pr. Hale's rockets.

Both units would usually be required for a siege.

The 64-Prs. are needed to dismount the artillery of the fortress by direct fire, frontal or enfilade, at long ranges; the 8″ howitzers to bombard the interiors of works, or of the place itself, by high angle fire at long ranges, with heavy shells of large capacity; and to enfilade lines provided with traverses, and breach unseen masonry, by indirect fire at shorter ranges.

The lighter pieces are needed for the more advanced artillery positions, to save as far as possible the labour of moving forward the larger calibres, perhaps under the fire of the fortress, and also to lessen the weight of the ammunition to be brought up.

The number of units of both kinds required would depend on the character, armament, and garrison of the fortress. For a small place, probably four units (120 pieces) would suffice; for a large fortress, with detached forts and a numerous garrison, perhaps three times as many would be required.†

* At Strasbourg in 1870 the garrison was 20,000, and the Siege Corps 60,000 strong, and the siege was pushed with great vigour. At Belfort the garrison was over 16,000, and the Siege Corps, at first only about 10,000, was gradually increased to 36,000; but the siege made slow progress and the place was not taken. At Thionville the garrison was 5,000, and the Siege Corps about 15,000; the place surrendered after the opening of the first parallel.

† The German Siege Trains in 1870 were often very small: at Thionville 61 pieces, Mézières 68, Toul 31, Longwy 52, Neuf-Brisach 34 (excluding field guns). But the French fortresses were known to be ill-armed and ill-adapted for defence. For the siege of Strasbourg the besiegers collected 373 pieces at the depôts, but used only 243. At Sebastopol, when the last bombardment opened, there were 698 pieces in the besiegers' batteries.

The extent to which the main lines of the ramparts can be enfiladed, owing to their trace and to the nature of the surrounding ground, must also be taken into account. Where frontal fire is employed for dismounting, at least gun for gun must be allowed; but where it is possible to employ enfilade fire, a less number will suffice.

In addition to the pieces of the siege train, field guns will be made use of, to assist in driving back the garrison in the first instance into their works, and in repelling sorties afterwards, &c.

461. *Ammunition.*—Each piece of the siege train is accompanied by 500 rounds of ammunition. This is enough to begin with, but in a siege of 30 days double this quantity is likely to be wanted, and supplies must he brought up as required. According to German experience the daily expenditure per gun ought seldom to exceed 60 rounds.*

462. *The Investment.*—This should be executed rapidly, if possible by surprise, and simultaneously on all sides, in order that the place may not be provisioned or reinforced, or have time to prepare for defence. The investing corps, which should be at least one and a half times the garrison, and especially strong in cavalry, should advance in several columns, carefully timed so that the heads of the columns may all close upon the place, by the various main roads leading to it, a little before daybreak.

In the investment of a large fortress with a powerful garrison the operation could not, probably, be carried out simultaneously on all sides. The operation would then have to be made gradually. The whole force would advance upon one side of the place, and the leading corps would take up a position on this side to receive an attack, so that under cover of this position the other corps might move round successively, and form up on the flanks, until the circle was completed.

The investing force would press in as closely as possible towards the place, so as to shorten the investing line and facilitate reconnaissance. With a garrison who perform their duty well, and cling to defensible posts, &c., in the environs, it will seldom occur that the main bodies of the investing corps can establish themselves nearer than $2\frac{1}{2}$ miles from the place, with their outposts pushed forward a mile or more to the front.

At about these distances the lines of investment will be systematically taken up, so as to secure a strict blockade. The whole line will be divided into sections, as the ground may dictate; the troops (divisions or brigades) assigned to each section supplying their own outposts and reserves. Good communications will at once be established between the different sections, to allow of prompt mutual support, and lines of field telegraph made to connect them all with the head-quarters.

The fighting positions selected are hastily intrenched for immediate defence, and the works gradually strengthened afterwards, so as to be able to resist the most powerful attacks that the garrison are able to make.

If the force be too weak to invest a fortress on all sides without a dangerous dispersion, it must choose a position favourable for defence, barring the roads which are of most value to the garrison; and by cavalry detachments and flying columns it may narrowly limit the communications of the place with the country, until reinforcements arrive and the investment can be completed.

463. *Choice of the side of Attack.*—Immediately after the investment the besiegers make reconnaissances, to correct and complete their plans of the fortress and the neighbourhood, and to decide how and where to attack it.

As regards the point of attack, it has to be considered—

(1.) On which side trenches can be most easily made.

(2.) Which is the best work to attack, as regards the effect of its capture on that of the fortress.

* At Strasbourg about 200,000 rounds were fired from 240 pieces in 36 days, and at Belfort 100,000 rounds from about 90 pieces in 72 days. At Sebastopol nearly 150,000 rounds were fired in 3 days from 698 pieces.

(3.) Which of the fronts, otherwise suitable, best satisfies the strategical conditions, is most convenient in relation to the line of supply or retreat, and will give the greatest security against attempts to relieve the place.

On account of the immense weight of the ammunition and other material now required for a siege, the position of the railway or river by which it is brought up must have great influence in determining the side upon which the fortress should be attacked, so as to lessen the road transport as much as possible, and allow the main depôts to be covered by the bulk of the siege corps.

Taking all these points into account, the Commanding Engineer, in concert with the Commanding Officer of Artillery, draws up a *project of attack*, showing generally its probable extent and ultimate direction, and submits it to the Commander of the Siege Corps.

464. As soon as the plan of attack is decided on, the position of the *Artillery* and *Engineer Parks* is fixed, and the artillery and engineer trains are there stored. These parks, or main depôts, should be out of range of the enemy's guns, especially the powder magazines: these latter should ordinarily be four or five miles from the most advanced works of the fortress. The ammunition depôt and the gun park may lie rather nearer, and the engineer park nearer still, but should be hidden from view. They should all be in railway communication with the line of supply.

Intermediate depôts are established as soon as the besiegers' progress will allow of it, usually one on each line of approach, and a mile or a mile and a half from the place, to contain the supplies required for 24 hours. These feed smaller *trench depôts*, and are themselves fed from the engineer park, with which they should be connected, if possible, by a line of railway or tramway.

During the investment* gabions, fascines, &c., are made up in the nearest woods, and transported to the parks: supplies of all kinds necessary are brought up until the besiegers are in a position to commence active operations, *without fear of being afterwards delayed for want of materials:* telegraphic communications should be perfected, and observations formed in convenient positions.

Reconnaissances all round the fortress should be made in order to mislead the garrison as to the intended point of attack.

465. *First Artillery Position.*—The first operation of the regular siege consists in forming a series of batteries at ranges varying from 2,000 to 4,000 yards from the place, for the purpose of silencing by frontal or enfilade fire the guns which bear on the field of attack. The closer these batteries are made, the more effective will be their fire. The choice of site will depend on the nature of the ground and the cover it affords. Considerable choice of situation will exist, so as to enable these batteries to be made and armed without interruption from the garrison, and possibly without their knowledge.

They can be widely dispersed, so as to be able to obtain to the fullest extent the advantage of convergence of fire; and in the case of a small fortress such as is shown in Plate XLII., they will embrace a semicircle, or even more.

For convenience of supply and control they may be in groups, but, unless the site compels it, there should seldom be more than five or six guns in one battery.

All the more important faces of the fortress which bear upon the field of attack should, as far as may be possible, be enfiladed by one battery, and *counter-battered* by the direct frontal fire of another. Often a battery while counter-battering one face may enfilade another, and perhaps take a third in reverse.

When enfilade is impracticable, the counter-batteries must be largely increased, so as to overpower the face by a superior number of pieces.

Many of these batteries being hidden from view, can be worked at before the arrival of the siege train, and will be ready to be armed when required: others

* The *investment* (or blockade, for it is such) is kept up until the siege is terminated; but the term is used here in its general sense, to imply the period which elapses before the "opening of the trenches."

will have to be made in more exposed situations, and will require to be screened from the enemy's view by branches of trees, &c.

The batteries of the first artillery position will be chiefly armed with the heavier pieces of the siege train, which, so far as is possible, should be placed in situations where they may continue to fire with effect throughout the siege, and will therefore not require to be moved to more advanced positions afterwards.

Arrangements are made for completing the armament of the whole of the batteries in the first position, so as to be able to open fire at daylight on a given morning.

466. *Opening fire from first artillery position.*—All the batteries should open fire at daybreak, and together, so as to anticipate the fortress, and get the advantage of observing their own shots and making the necessary corrections before they are exposed to a reply. The daily expenditure of ammunition will be fixed by order, and only exceeded under very special circumstances; but to provide for such cases the magazines should contain a two days' supply, or 100 to 200 rounds per gun. The fire will be slackened, but not entirely suspended, during the night.

As soon as the artillery fire of the place is sufficiently subdued, the besiegers will form their *first parallel*, or *place of arms*.

467. *First Parallel, or Place of Arms.*—Parallels and demi-parallels, termed also *places of arms*, are trenches running parallel, or nearly so (whence their name), to the general front of the works attacked.

Their object is to protect the batteries and other works of the attack (in case of sorties being made from the garrison) by holding *a guard of the trenches* sufficiently strong to repel such attempts. At the same time they afford a covered communication between the different works of the attack, and allow of a great amount of musketry fire being kept up from them on the defences.

Their extent must be sufficient to embrace the salients attacked, and to support any batteries that may be made on the flanks of the attack.

They are terminated by *returns*, to bring a fire of musketry on sorties attempting to get round their flanks; sometimes their extremities are strengthened by redoubts.

The first parallel will usually be about 800 or 850 yards from the place.

This distance is such that musketry fire from the fortress will not be effective while it is being commenced at night, but will permit musketry fire from it, during the day, to be kept up on the defences.

The mode of tracing and executing the first parallel by *common trench work* will be found described in Arts. 478, 484.

468. On the night fixed for its construction, the outposts must be strengthened on the fronts of attack, and with their reserves and the main body they constitute the *covering troops.* They should push forward a line of double sentries about 300 paces in front of the intended parallel, with the piquets about 100 paces behind them, or 200 paces in front of the parallel. The supports—say half a battalion for each half-battalion of the outposts—should be 100 paces in rear of the piquets, and about the same distance in front of the parallel, so that their advance in case of a sortie should not disturb the workmen.

The reserve, comprising cavalry and artillery as well as infantry, should be about half a mile in rear of the flanks, as its especial duty is to guard against flank attacks.

The total strength of the covering troops should usually equal or exceed two-thirds of the strength of the garrison.

At daybreak the "covering parties" either take post in the parallel or behind any available natural cover; henceforth they are termed the "Guards of the Trenches."

To enable the guards to pass to the front of the parallel to repel sorties, parts of it are prepared with steps, as in Art. 490.

469. *Approaches.*—Three or more approaches are usually found necessary for the attack of any important front. Of these, one at least must be opened at the same time as the first parallel, to serve as a covered communication from it to the rear. These approaches are made in zigzags, the prolongations of which fall alternately to the right and left of the fortress, and about 100 yards clear of the most prominent salients of the covered way, to prevent their being readily enfiladed.

They are usually kept on the capitals of the works attacked, as there they are less exposed to frontal fire from the place, and least in the way of the besiegers' own batteries. Each branch of a zigzag overlaps the branch behind it by about 10 yards, screening it from enfilade view, and at the same time forming a *return* which may be useful as a trench depôt for engineer stores.

The above remarks on the trace of the parallel and of the approaches are illustrated in Plate XLII., which gives a general sketch of the systematic attack on a small bastioned fortress up to the foot of the glacis. In this sketch it is assumed that the first artillery position can be placed at about 2,000 yards from the fortress; that on the right flank it can be extended so as to enfilade the faces bearing on the field of attack, but that on the left flank such extension is forbidden by special circumstances.

470. *Reliefs.*—The guard of the trenches is relieved once in twenty-four hours, usually about mid-day. For the working parties the reliefs are of six or eight hours; but the men of each company are marched off as soon as their task is finished.

Short reliefs are best when the numbers are small; but with the very large working parties required for the first few nights, frequent changes involve risk and confusion, and not more than two reliefs can be reckoned on in twenty-four hours.

The duty should be taken by companies and battalions under their own officers, and not by mixed detachments.

The engineers are relieved at intermediate hours to the infantry working parties.

As all new work is generally begun at nightfall, in order to get good cover by morning, successive periods of twenty-four hours are at sieges reckoned by nights instead of days, and begin at dusk.

471. *Second Artillery Position.*—The distance of the batteries of the first position will make it difficult for them, without excessive expenditure of ammunition, to silence the fortress altogether, and to defeat the efforts of the garrison to reopen fire.

As soon, therefore, as the first parallel is securely established, a second artillery position will be taken up in rear of it at from 900 to 1,500 yards from the place. The batteries of this position will be armed partly by fresh pieces from the parks, partly with pieces moved forward from some of the batteries of the first position. Their functions are more strictly defined than those of the more distant batteries, and their several positions are in closer connection with the trace of the fronts to be attacked.

They comprise—

(1) Batteries for enfilading with curved fire the most important faces.
(2) Counter-batteries for direct fire on the principal faces bearing on the attack.
(3) Batteries for high angle fire, to search out the interior of works, especially those which cannot be enfiladed.
(4) Breaching batteries for curved fire, to breach the escarps and flanking casemates, if possible, from a distance.

These will usually act as enfilade, counter, or high angle batteries, until the last stage of the attack. Some of these batteries would be established in the first parallel.

The batteries of the second position, from their proximity to the place, will be subject to a heavy and accurate fire from the fortress. Their construction and the operation of arming them will be effected under considerable difficulties. Every effort must be made to construct and arm them in a single night.

When the batteries are ready they will open fire simultaneously at day-break, supported by the musketry fire of the parallel and by the heavier guns left behind in the first position.

The engagement must be continued day and night, usually at about 60 rounds per piece in 24 hours, until the artillery fire of the defence is completely broken down. This result is to be looked for, partly from the besiegers' superiority in number of pieces, but still more from the convergence they can give to their fire ; from the easy mark offered by the ramparts of the fortress, as compared with their own screened and scattered batteries ; and from the effect which even ill-aimed shells will produce in some part or other of the works.

472. *Advance from the 1st Parallel.*—As soon as the first parallel is securely established, and the fire of the place sufficiently brought under, approaches by zig-zag are resumed upon the capitals of the works attacked ; and at rather less than half-way from the first parallel to the fortress the heads of these approaches are connected by a *second parallel,* which is required to support the works to be made in advance.

This parallel will, if possible, be executed like the first parallel, in one night, by extended working parties, protected by covering troops. But the besiegers are now within effective musketry range, and it becomes more urgent than ever to get cover quickly. Each man, therefore, of the working party is usually provided with two gabions, which he places in front of him on the tracing line of the parallel, and fills as rapidly as he can, so as to obtain a musketry-proof parapet in about half an hour. This parapet is then gradually thickened, the gabions forming an interior revetment ; and the trench behind it is enlarged to the same dimensions as the first parallel.

This method of execution, termed *flying trench work* (Art. 487), may have to be employed also for the approaches in advance of the first parallel, instead of common trench work, if the fire from the fortress renders it necessary.

473. Flying trench work will continue to be made use of in the further approaches in advance of the second parallel whenever the passiveness of the defence gives opportunity for it. But the musketry fire of the place, from its proximity, now becomes much more accurate, and the ground over which the besiegers have to advance can be much more thoroughly lighted up, so that even by night they cannot hope for concealment from a vigilant garrison. In fact, day may become more favourable than night to their further progress, as allowing the workmen to be better supported by the fire of the batteries and parallels behind them. It is generally assumed that the besieger somewhere between the 2nd and 3rd parallels will have to give up the method of flying trench work for forming his trenches, and that henceforward he must be mainly dependent on the regular *Sap.*

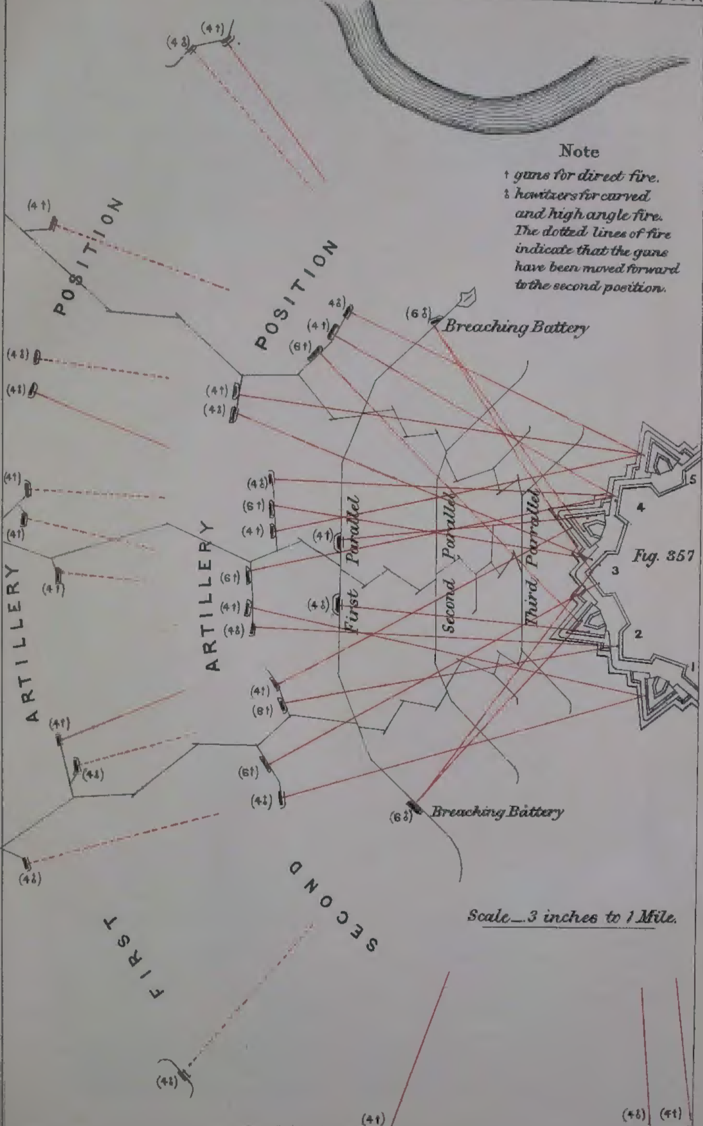
474. In this operation (*Sapping*) there is no extension of large parties of exposed men for the simultaneous execution of the work, but one man (a trained *Sapper*) works forward along the line of the intended trench, covering himself by a parapet as he advances, and is followed by other Sappers who widen his trench and thicken his parapet, until cover from musketry is given to men standing upright.

The trench thus formed by sap is widened to the required dimensions by infantry widening parties, working in the usual manner at 5 feet intervals.

The rate of progress of the *Sap heads* therefore regulates the progress of the siege, and every effort must be made to push them rapidly forward, and to increase their number, or to gain ground by flying trench work whenever a favourable opportunity may occur. At the siege of Strasbourg the latter was largely employed even up to the crest of the glacis.

The approaches between the 2nd and 3rd parallels, though executed by a

Pl. XLII Fig 357.



Scale _ 3 inches to 1 Mile.

different method from those between the 1st and 2nd parallels, will usually correspond to them both in profile and trace; but as by this time the garrison must be confined to their works, it will be sufficient if the prolongations of the branches of the zigzags pass 40 yards outside of the salients of the covered way, which will protect them from enfilade.

475. Owing to the advanced position of the 3rd parallel, the Sappers pushing forward the approaches would, before they reached it, find themselves nearer to the enemy than to their own supports in the 2nd parallel. *Demi-parallels*, 100 to 150 yards in length, are therefore made on each approach, about half-way between the 2nd and 3rd parallels, to receive some detachments of the guards of the trenches. These demi-parallels should be well furnished with loop-holes for musketry fire, and with sortie steps to allow the guard to advance over.

The Sap heads are also guarded in their advance by riflemen in pits, about 30 yards ahead of them.

Sometimes the parallels or approaches will be found to obstruct the fire of some of the batteries, and it may be necessary to make nearer batteries as substitutes for them; but it will probably be the exception to bring forward siege guns in advance of the 1st parallel. Light pieces for high angle fire (such as the 7-Pr. Mountain gun) will, however, be largely employed in the 2nd and 3rd parallels and the demi-parallels to drive the garrison out of the covered way, and they will usually be placed in the prolongations of its branches, so as to enfilade them.

476. *The 3rd Parallel* is usually placed at the foot of the glacis, or about 100 yards from the salients of the covered way. As this parallel serves as the base for the close attack, to gain possession of the glacis and covered way, it is important to have it as far forward as possible: a more advanced position would, however, bring it within reach of the enemy's countermines, if these exist.

It is extended on either flank as far only as is necessary to envelope the works attacked. It is formed by simultaneous saps (six in Plate XLII.) diverging from the heads of the several approaches.

With an active and resolute garrison, the besiegers' working parties will be harassed by fire, and small sorties, more and more as they get nearer to the place. It is necessary, therefore, that the 3rd parallel even more than those behind it should be well prepared for meeting the enemy in the same fashion: its crest should be furnished with loopholes for musketry fire, and steps should be made, at frequent intervals, to allow the guard to advance from it.

Execution of Siege Trenches.

477. The "Queen's Regulations" lay down that "it is of the utmost importance that at Sieges and on field service, working parties should be detailed by companies, battalions, brigades, and divisions as required, and not be formed by detachments from different companies and corps. The officers should be with their respective companies or corps. The officers and non-commissioned officers of the working parties will be held responsible for the *amount* of work done; the duty of the Engineers being to see that the labour is *properly applied*." (Section VIII. par. 76.—1883.)

Working parties should be relieved at intervals not exceeding eight hours; but for works that have to be executed in a short time it is better to have *six-hour* or *four-hour* reliefs, so that the men may be replaced by fresh hands before they are unduly fatigued.

As a general rule, the Engineers should at Sieges work in eight-hour reliefs, and should not be relieved at the same time as the Infantry.

When the work is continued for any length of time, as in Sieges, the working parties, both Engineers and Infantry, should, if possible, have three tours off duty (amounting altogether to not less than 24 hours) to one tour on, *i.e.*, working parties should for a continuance be calculated to supply four reliefs or relays.

In the execution of siege works and of field works under fire or within range of the enemy, secrecy is indispensable. For this reason, all tracing should be done at dusk, so that there may be sufficient light for the work, while at the same time the enemy cannot perceive what is going on.

All excavations within range of the enemy in which a number of men are employed should be commenced under cover of darkness, and every effort made to obtain sufficient cover to protect the men before daylight. The great power of modern shells also makes it almost imperative in many cases, such as the construction of siege batteries at close ranges, that the work should be practically completed by that time, leaving nothing but the elaboration of small details to be done subsequently. These are the occasions for the employment of short reliefs. In all cases in which a work requires two nights for the excavations, these should be executed during the dark hours of those nights.

Of course a departure from these rules may be warranted by the want of vigilance of the enemy, or the slackness of his fire.

Tracing and Extending Workmen. (Plate XLIII.)

478. The position of the line or lines to be traced should have been settled beforehand, and landmarks, not easily observed by the enemy, left to enable the tracing party to work without delay or error in the dusk.

In sheltered situations it is a good plan to post sappers during daylight to await the arrival of the party, as these animate points can be more readily found however dark the night.

The tracing is executed by the engineers. The tape used for the purpose is in 50-yard lengths, each wound on a picket. As many sappers are required as there are tapes, *i.e.*, one to every 50 yards of line to be traced; they are accompanied by an officer and a non-commissioned officer, the latter of whom carries a lantern,* a picket and a mallet, while each sapper carries a tape and a 6-ft. rod.

When the party arrives at the starting point of the tracing (Fig. 358), the leading (No. 1) sapper halts and gives the end of his tape to the officer, who marches on with the rest of the party in the direction of the line to be traced. When the tape is completely unwound, No. 1 sapper sticks his picket into the ground, and No. 2 sapper halts and gives the end of his tape to the officer; when this second tape is unwound, No. 2 sapper sticks his picket into the ground, and fastens the end of No. 1's tape to it; and so the tracing goes on until all the sappers are extended, when they face the starting-point and lie down to await the arrival of the working parties. The officer returns to meet the working parties and to conduct them to their proper sections.

In tracing approaches the zigzags are traced first without noticing the *returns*, and the latter (10 to 20 yards long) are afterwards traced separately with tapes of the required length; a portion of the tape at every change of direction of an approach must be cut, in order to clear the trench to be excavated. This is shown in Fig. 359. D A E is the traced angle of the zigzag. A distance of 15 feet is measured from A to B, and the tape cut and a picket driven at B. The length A B is then wheeled round into the position A C, in prolongation of E A, and fixed to a picket at C.

When the working parties arrive, the sappers of the tracing party assist in extending them along their own 50 yards, and afterwards superintend the execution of the work.

479. The tracing having been executed in sections corresponding with the length of line required for the several working parties, the latter should be provided with a reserve of 10 per cent. to replace casualties, and to relieve individual diggers at the discretion of the officer in charge.

* This is of a special pattern, and is intended to throw light in a downward direction.

It is undesirable, under any circumstances, to extend more than 500 men from one point.

The men parade in fatigue dress, with rifles slung, waistbelts, bayonets, ammunition pouches with 20 rounds, and filled water-bottles.

They are marched to the intermediate engineer depôts which have been established at convenient places screened from the fortress, in sufficient time to receive the tools, and to be in readiness to march off on the arrival of the engineer officer of the tracing party.

They are drawn up in column of companies, with the reserve of 10 per cent. in rear of the column, and sappers, in the proportion of one to every 30 men, on the reverse flank of each company.

Owing to the difficulty that is invariably experienced in practice, of arriving at the exact numbers of the working parties that the officer commanding the infantry can furnish, it will be impossible to lay out the precise number of tools for each company; but arrangements must be made beforehand for their most speedy distribution, either by laying them out in rows, or by having a proportion in rows and the remainder in heaps, as may appear desirable.

In laying out tools in rows, the sets should be one pace apart, with an interval of two or three paces between the rows. Fig. 361 shows the usual details of arrangements. The ranks of men are marched behind the rows of tools, each man in rear of a set. They are carried at the trail, pick in left hand and shovel in right, iron to the front, and point of pick downwards. In marching in file the handles should be inclined outwards to enable the files to close up.

When tools are arranged in heaps, the picks should be in one and the shovels in another (Fig. 360) a few paces apart, with two sappers at each heap to issue them. The men file past in single rank between the two heaps, keeping the picks on their left and shovels on their right; on receiving the tools they form up on their markers.

480. The regulations of the service with regard to working parties are—

(1) Each man is to be shown the task he is to execute.
(2) Arms, when laid down to commence work, are not to be taken up again, even in case of attack, except by order of the commanding officer.
(3) Strict silence is to be kept, and all clashing of tools or arms to be avoided.
(4) Words of command are to be given in an undertone of voice.
(5) No lights or smoking are allowed.

On the arrival of the engineer officer of the tracing party, the column is marched off in fours, file or column, as best suits the ground, and is conducted by him to within 20 paces of the point of extension, where it is formed in quarter column and halted (Fig. 362).

481. If the extension is to be to the *right*, the column is formed *left in front*, and *vice versâ*.

The general command for the extension is—"*By successive companies extend to the right* (*or left*) *at two paces' interval;*" upon which the commander of the leading company gives the words—"*Left turn,—right wheel,—quick march,*" and when the leading file has reached the point of extension, "*right wheel*" (for extension to the right), "*left form in extended order.*" The remaining companies follow without intermission in file, getting the same words of command at the proper time.

As the men come up along the tape, the sappers of the tracing party measure off 5 feet lengths for each man,* who then drives his pick into the ground at the left of his task, and lays his shovel on the ground just behind the tape (Fig. 363). Arms are then unslung, and waist-belts taken off and laid on the ground,

* The tape is sometimes marked at 5 feet intervals by short pieces of tape tied to it.

and all await the order to "*commence work.*" The reserve of the working party is posted in rear of the centre of the extended line.

In extending on approaches, when the angle of a zigzag has been reached, the order of forming must be reversed, the command being merely changed from *right (or left) form*, to *left (or right) form.*

One hundred men can be extended in about five minutes.

482. The sappers of the tracing party return to camp with the first relief. Those who came with the first relief remain to take charge of the tools, and on the arrival of the second relief place themselves as did those of the tracing party, assisting also in posting the men on their tasks. The tools should have been left by the first relief in rear of the trench.

When no fascines are carried to form steps in a parallel, the second relief is extended in the same way as the first. They should parade early enough to allow of the first relief being relieved and marched back to camp before daybreak.

483. When the fascines have to be brought up, the working party must be formed in column of companies of 36 files each, with ranks at *open order*. The fascines are previously laid out on the ground in column of rows (10 to each row), the fascines in each row touching. (Fig. 365, Plate XLIII.)*

The men are filed on to the fascines, each rank passing behind a row. Three men are then told off to each fascine as carriers. The remaining six men of each row march, one at each end of the row, and one between every pair of fascines, and carry the pickets.

Instead of forming to a flank, as in the first relief, the column will be *deployed* to the right or left, the pivot flank of the leading company resting on the point of extension. The fascines will be deposited on the ground three paces in rear of the excavation made by the first relief. They must be made to butt end to end, and great care must be taken that no distance is lost in deploying, so that no closing need occur afterwards.

Common Trench Work and Flying Trench Work.

484. *Common Trench Work* is the term applied to the mode of executing a trench with a rough unrevetted earthen parapet in front of it. The working parties are necessarily much exposed at the commencement at the work, and for this reason the method can only be employed when they may reasonably hope to escape without much loss from the enemy's fire, while sufficient cover is being obtained; this they will hardly do in less than an hour and a half.

The first parallel and communications in rear of it would usually be executed by common trench work.

In this and similar work it is advisable to adopt eight-hour reliefs; for although the tasks given are frequently such as might, under favourable circumstances, be executed in four hours, yet the liability to interruption and other causes make it better to be on the safe side.

485. Fig. 366, Plate XLIV., shows the complete profile of a parallel executed by common trench work. The Roman numerals indicate the portions done by each relief, and the figures enclosed in circles are the contents, in cubic feet, of the tasks.

The men are extended at the usual interval of two paces (5 feet) in each relief.

The first relief throw the earth so as to leave a berm of 3 feet 4 inches† in front of the line traced by the tape, the latter having been removed and wound up by the sappers as soon as the tasks had been marked out.

* Ten 18 feet fascines, when placed in the parallel, occupy 180 feet of front; and in order that the men may be extended at the usual 5 feet interval, there must be 36 men to every 10 fascines.

† The berm is required to be about 1 yard wide, and the precise dimension 3 feet 4 inches is chosen because it is the length of a shovel, and each man has thus a ready means of measuring the berm for himself.

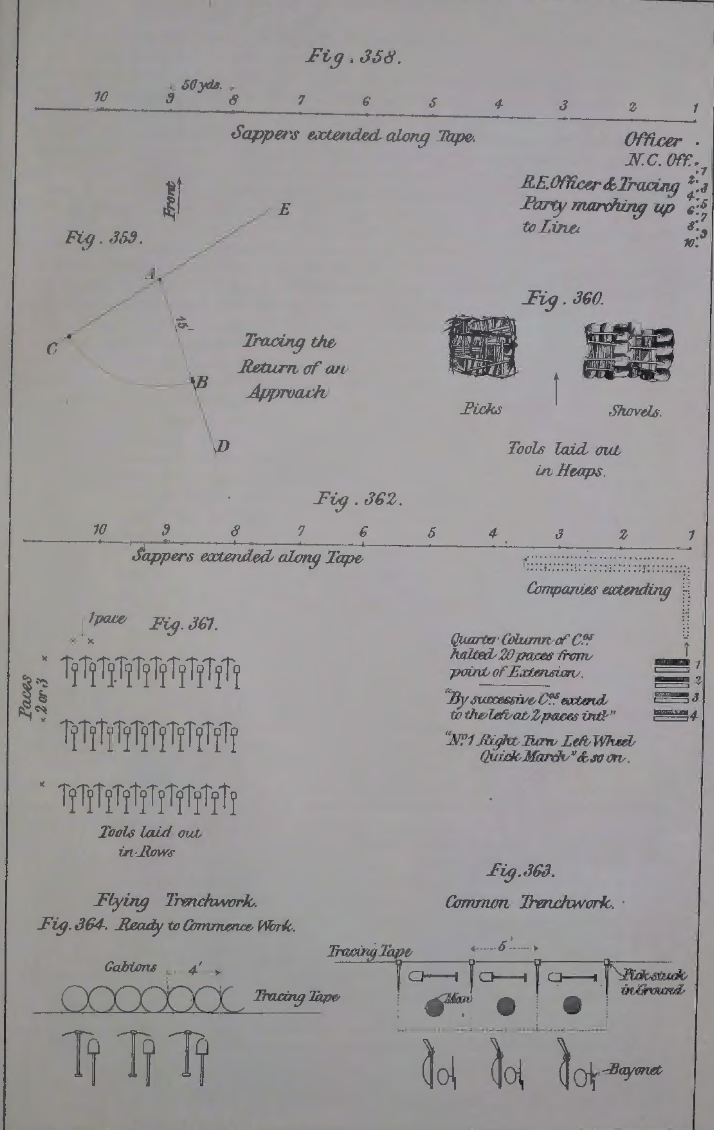


Fig. 358.
50 yds.
10 9 8 7 6 5 4 3 2 1
Sappers extended along Tape.
Officer
N.C. Off.
R.E. Officer & Tracing Party marching up to Line.
Fig. 359.
Front
E
A
C
B
D
15
Tracing the Return of an Approach
Fig. 360.
Picks
Shovels.
Tools laid out in Heaps.
Fig. 362.
10 9 8 7 6 5 4 3 2 1
Sappers extended along Tape
Companies extending
Quarter Column of C.os halted 20 paces from point of Extension.
"By successive C.os extend to the left at 2 paces int.l"
"N.o 1 Right Turn Left Wheel Quick March" & so on.
1 pace
Fig. 361.
Paces 2 or 3
Tools laid out in Rows
Fig. 363.
Common Trenchwork.
Flying Trenchwork.
Fig. 364. Ready to Commence Work.
Cabions
4'
Tracing Tape
Tracing Tape
6'
Pick stuck in Ground
Man
Bayonet

In commencing the excavation, each man digs a hole about 3 feet in diameter at the left front of his task, working it out to the full depth, so as to get cover as quickly as possible; he then lengthens it to the full, and finally widens the trench to the assigned limits of his task.

In using the pick, great care must be taken that the men swing the handle in a direction perpendicular to that of the trench, as otherwise, being closely placed and in the dark, they may damage their neighbours.

The second relief have to widen the trench 4 feet, to cut out the top step, leaving a berm of 1 foot 10 inches, and partly to form the bottom step with sods and earth.

The third relief widen the bottom or sole of the trench 2 feet 6 inches, and slope off the reverse as steep as the earth will stand (say $\frac{2}{1}$).

The fascines with which the bottom step is revetted (Fig. 366) are sometimes brought up by the second and third reliefs, as described in Art. 483, but usually the step is revetted after the parallel is completed.

The crest of the parapet must not be higher than 4 feet 6 inches above the ground, so as to admit of musketry fire over it.

Whenever extra men can be spared, it is advisable in the third relief to provide one shoveller to every two diggers, as the throw is both long and high. The shovellers should stand on the first step, and pass on the earth thrown to them by the diggers.

486. Approaches and communications are made of the same section as the parallel, except that it is not usually necessary to step them for musketry fire, although it is sometimes advisable to do so. Fig. 367 gives a profile of an approach of full width, requiring three reliefs. Those over which little traffic is likely to pass may be made in two reliefs (Fig. 369), the width at the sole of the trench being reduced to 9 feet.

The first relief have exactly the same task as in the case of a parallel.

The second and third reliefs have no materials to carry to the trenches; the second relief cut a front slope, having a base of 1 foot 6 inches, leaving the same berm (1 foot 10 inches) as in the case of parallels.

487. *Flying Trench Work.*—To diminish the duration of the exposure incurred by a working party in commencing trenches, the method of *flying trench work* (formerly termed *flying sap*) is resorted to. This consists in placing a row of gabions along the front of the tracing tape, and proceeding to fill them as quickly as possible with the earth excavated from the trench; after which the earth is thrown over them, to back them up and form the parapet. Of course in the earlier stage of the work the junctions of the gabions are the weak points, but the cover afforded on the whole is undoubtedly very superior to that obtained by common trench work.

It is generally considered that this method is applicable to the second parallel and its communications.

The gabions required for the work should be carried down by a special party during the day preceding the opening of the second parallel, and stowed in a single row along the reverse of the first parallel. Iron-band, wire-net, or other light gabions, two of which can be easily carried by one man, should if possible be used.

The first relief parade as for the first parallel, and are marched to the engineer depôt to receive their tools, after which they are formed up in single rank in the first parallel, along the row of gabions already there, each man standing opposite a pair of gabions, in one of which (the right) he secures his shovel, and in the other (the left) his pick.

The blade of the shovel is secured between two of the gabion pickets, and the point of the pick pushed under the pairing rods, to prevent its slipping.

When iron-band gabions are used, the tools are secured in them by means of spun-yarn.

The men, each carrying his two gabions, are marched in single rank to the point of extension, and extended in rear of the tape, as described in Art. 481, in sections of not more than 250 men each, to avoid delay and straggling.

Each man places his gabions in front of the tape, and close to it, taking care that they touch one another, and that no space is left between them and the gabions last placed (Fig. 364, Plate XLIII.). In this duty the sappers assist. Each man then takes the tools and carrying pickets out of the gabions, places the tools in rear of the gabions, and lies down.

When all the gabions are placed, the tracing tape is moved back 3 feet 4 inches (the width of the berm to be left by the first relief), to mark the front of the tasks, and all await the order from the engineer officer to commence work.

It will be remarked that the men are extended at 4 feet intervals, the space occupied by two gabions.*

488. The profile of the second parallel (Fig. 370) and the dimensions of tasks are the same as those of the first parallel, excepting that the interior slope of the parapet stands at $\frac{4}{1}$, and the length of the trench executed by the first relief is 4 feet instead of 5 feet.

The first relief fill their gabions as quickly as possible, and then back them up by throwing the earth just over them, so as to make them bullet-proof; after which the earth is thrown well to the front to form the parapet. The slope of $\frac{4}{1}$ is given by pushing the gabion forward at the top when it is half full.

The second relief being placed at the ordinary intervals of two paces, their strength should be four-fifths of that of the first relief: therefore, every fifth man of the first relief will, after completing his task, return his tools to the engineer park.

The carrying pickets and tracing tapes should be collected by the non-commissioned officers, and returned also to the park. The tools left by one relief are placed by the sappers in rear of each man's portion, ready for the next relief.

489. When the ground is unfavourable for excavation on account of rock or water being found near the surface, the profiles before given must be altered to suit each particular case. In some cases (as actually did occur at Sebastopol in 1854) it may be impracticable to excavate at all, and the parapet must be formed of earth brought up in baskets or sand-bags from the nearest point. It is hardly necessary to remark that such sites are always avoided unless actual necessity dictates their occupation.

In rocky and marshy ground alike, as the trench must be shallower, the parapet must have an unusually high command, in order to give sufficient cover; the trench must therefore be broad enough to furnish the proper quantity of earth (Fig. 371).

In marshy ground excavation may be carried on till the men are knee-deep in water. The profile given in Fig. 372 offers the greatest facilities for obtaining earth and securing good drainage.

Irregularity of ground not only affects the plan, but also the profile, of parallels and approaches. Reverse slopes, unseen from the fortress, offer the advantage of providing the same cover with less labour, or superior cover with the same labour; or even in some cases the cover provided by nature may suffice. But on the other hand, when trenches have unavoidably to be constructed on ground falling towards the fortress, more cover may be required than that which is provided by the ordinary profiles. The modifications suitable to each particular case must depend on the relative slopes of the sole of the trench and of the enemy's fire.

490. To provide for the advance of the guard of the trenches over the parapet of a parallel, when repelling sorties, &c., it is necessary to make *sortie steps* at intervals. (Figs. 373, 374, Plate XLIV.) They should be at least 30 paces

* In case of great exposure, the men may be extended under cover of Donnelly's sap-shields, which are of $\frac{3}{16}$″ steel, and 3′ 6″ high, and 1′ 9″ wide. As each shield requires a man to carry it, there must be a special carrying party.

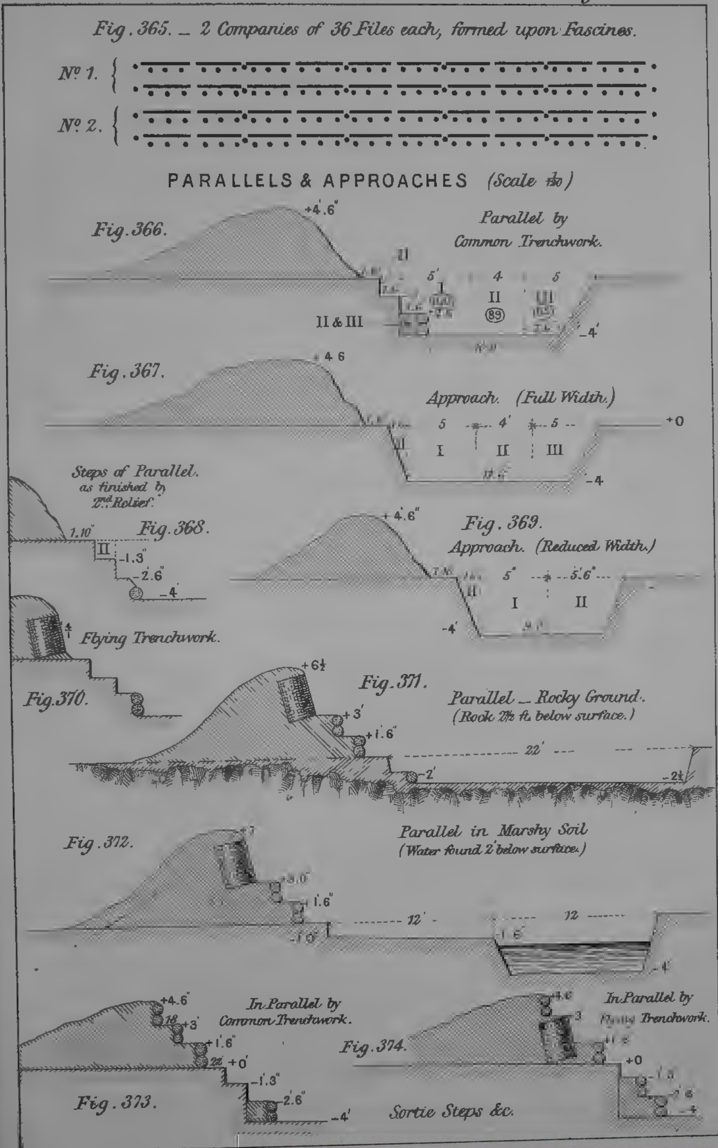


Fig. 365. _ 2 Companies of 36 Files each, formed upon Fascines.
Nº 1.
Nº 2.
PARALLELS & APPROACHES (Scale 1/80)
Fig. 366.
Parallel by Common Trenchwork.
+4.6"
II & III
89
-4'
Fig. 367.
Approach. (Full Width.)
+4 6
+0
I
II
III
-4
Steps of Parallel. as finished by 2nd Relief.
Fig. 368.
1.10"
-1.3"
-2.6"
-4'
Fig. 369.
Approach. (Reduced Width.)
+4.6"
5'.6"
-4'
Flying Trenchwork.
Fig. 370.
Fig. 371.
Parallel _ Rocky Ground. (Rock 2½ ft. below surface.)
+6½
+3'
+1.6"
22'
-2'
-2½
Fig. 372.
Parallel in Marshy Soil (Water found 2' below surface.)
+1.6"
12'
12
-4'
In Parallel by Common Trenchwork.
Fig. 373.
+4.6"
+3'
+1.6"
+0'
-1.3"
-2.6"
-4'
Fig. 374.
In Parallel by Flying Trenchwork.
Sortie Steps &c.
+0

in length (a company front being taken as the basis), and there may be three sets, one in the middle and one on either flank of the parallel.

They should be revetted with fascines, boards, or other available material, and are constructed by a special party, who should commence work as soon as the last relief has completed its task.

The steps should be ready by the evening of the first day.

In a parallel constructed by flying trench work, the second relief should not form the usual step at those portions where sortie steps are to be made (Fig. 374): the earth for the steps is obtained by cutting away the reverse slope, so as to preserve the full width of the sole of the trench.

491. The advanced sentries when posted in the open are sheltered in small trenches and pits, capable of holding from one man to a section of a company, as may be thought desirable. Communication may, if necessary, be established between any of the pits or trenches by means of any of the deeper forms of shelter trench given in Chapter I., along which men may creep, or crawl on hands and knees. Occasionally the position of these may correspond with that of a projected parallel, &c., and thus effect some saving of labour in the execution of the latter. Figs. 129, 130, Plate XIII., give a form of deep *rifle-pit* for one man.

Sand-bag or other loopholes, which have been before described in Chapter I., are especially necessary here.

In very exposed situations the pits might be constructed under cover of cotton-stuffed gabions, light sap rollers, or steel shields.

Sapping.

492. As explained in Art. 473, the advance by sapping is resorted to when the fire of the besieged prevents the further use of flying trench work. It is executed by sappers, and consists in constantly extending the end of a narrow trench (afterwards widened by the infantry) in the direction of the proposed approach or parallel, and throwing the earth to the front or exposed flank to give the workmen cover.

The rate of advance of saps is necessarily slow (3 to 12 feet an hour, according to the soil and the particular method employed), although in all cases the maximum rate is sought to be obtained by making the excavation executed by the sappers a minimum consistent with the due covering of the party.

When the parapet has to be thrown up on one side of the trench only (Plate XLV.), one party of sappers is employed for each *sap head*, and the process is called *single sap*.

When a parapet is required on each side of the trench, two parties of sappers work abreast, and the process is called *double sap*. In this case no widening parties are required.

The sap head is protected in either kind of sap by a shifting *head parapet* of sand-bags: or, in the case of single sap only, by a sap roller (Fig. 380, Plate XLV.), or other movable bullet-proof screen, pushed on as the sap proceeds.

In the execution of saps their uninterrupted progress is of the greatest importance, as the duration of the siege depends upon them.

To ensure this, the principle of double working parties is always adopted in this class of work; and as everything depends upon the exertions of the leading sapper, the maximum of work must be got out of him by frequent reliefs. The principle of taskwork also is here employed with advantage, as the men will naturally do their utmost to get away from a position in which they are so much exposed to fire.

Single Sap.

493. Single sap is of two kinds, viz., *deep sap* and *shallow sap*. The latter gives a quicker rate of advance (its depth being only two-thirds that of the former), and is employed when the fire of the enemy is slack, or when rock or water are found so near the surface as to prevent the use of the deep sap.

Plan and sections of the deep sap are given in Plate XLV.

The *sap detachment* for each sap head consists of one non-commissioned officer and eight sappers, who are on duty for a relief of eight hours. They parade in two ranks, with rifles, and with 20 rounds of ammunition per man in their pockets.

The ranks work alternately, relieving each other on the completion of each yard of advance, the waiting rank making good any casualties. Unless the detachment be reduced to less than four men, it will have to continue work without any additional sappers until the end of the relief.

The four men in the saphead work in pairs, the front Nos. I. and II. completing the section shown in Fig. 377, in which the side parapet is $2\frac{1}{2}$ feet high, and thick enough to resist rifle bullets (*i.e.*, about $2\frac{1}{2}$ or 3 feet thick, at 18 inches above the ground level). Nos. III. and IV. widen the trench and heighten the parapet, making a berm as shown in Figs. 375-6-8, always allowing Nos. I and II. 9 feet of start. The head parapet is about 2 feet high at the lowest part, and is composed of 50 or 60 sand-bags, each of them two-thirds filled, which are pulled down one by one as the sap advances, and either lobbed over the others by hand, or placed in position by means of a special fork provided for the purpose. A few spare sand-bags are always kept ready filled in a convenient position in the trench, for use if required.

The proper direction of the sap is ensured by means of a directing rod 15 feet long and $1\frac{1}{2}$ inch diameter, having one end rounded and shod with iron. It is laid on the berm, as shown in Figs. 375, 376, Plate XLV., secured by pickets on both sides, and the point of it projects 6 feet beyond the head of the sap. At distances of 3 and 6 feet from this end, small grooves are cut all round the rod to enable the men to find these measurements readily in the dark.

In order to vary the duties of each rank, whenever the waiting rank relieves, the Nos. that were I. and II. become III. and IV.; and, further, when a rank has worked half its time (*i.e.*, when the sap has advanced $\frac{1}{2}$ yard), Nos. I. and II. change places.

Nos. I. and II. set the directing rod.

No. I., kneeling or squatting to his work, undercuts the ground about nine inches in front of him, and brings down the earth at his feet. No. II. at once takes his place, and shovels the earth on to the side parapet, towards the head of the sap. No. I. resumes his place, and throws or places the sand-bags one by one just over the others, taking care to preserve a good bullet-proof parapet, until he has uncovered about one foot of ground at the sap head. He then removes 9 inches of this as before, and so the work goes on. No. II., in addition, has to trim the slope and see that the task is got out to the proper dimension.

Nos. III. and IV. throw their earth obliquely forward towards the sap head, and regulate the height of the parapet by means of an earth scraper.

When the non-commissioned officer gives the word *Relief*, all the Nos. rest their tools against the slope on the berm side, and pass to the rear, being immediately relieved by the other rank.

The new Nos. I. and II. set the directing rod on another 3 feet, and the work proceeds as before.

The non-commissioned officer is responsible for the direction, rate of progress, and correctness of profile of the sap.

The arms, while the men are at work, are laid on the ground at the reverse of the trench, as shown in Fig. 375.

This sap advances from $2\frac{1}{2}$ to 5 feet an hour.*

The sap is widened by parties of infantry, extended as in common trench work, who do not approach nearer than 25 feet to the sap head.

* Single saps are called *right* or *left handed*, according to the side on which their parapets are situated. If the latter is to the left when facing the fortress, the men use their shovels with the right hand on the T-head, and the sap is *right handed*, and *vice versâ*.

In the case of an approach not requiring steps, the task of the infantry is as shown in Fig. 379. It is exactly the same as that of the sappers, and should be done in one relief.

When, however, the parapet has to be made available for musketry fire, two reliefs are required, the tasks being as shown in Fig. 379. The second relief form the steps.

494. Shallow saps can be executed in two ways, viz., by *kneeling sap* or *standing sap*. In the former the trench excavated by No. 1. sapper is only 18 inches deep, and the rate of advance is about twice that of deep sap; in standing sap the trench is twice as deep, and the rate slower than that of kneeling sap by about one-third, but the leading sappers are better covered. The sap head is covered by a sap roller, mantlet mounted on wheels, or other bullet-proof mask.

The construction with sap roller will be here described.

The parapet is revetted with gabions sloping $\frac{4}{1}$, which are placed in succession by the leading sapper, leaving a berm of 18 inches (Fig. 381). The junctions of the gabions, as well as the most advanced gabion before it is filled, are covered by means of Knight's sap shields (steel plates mounted on wheels, *see* Fig. 382),* which move along the berm, the front one fitting close against the sap roller. The use of these shields is imperative for the kneeling sap; but in the standing sap, when shields are not available, sand-bags may be used to stuff into the junctions between the gabions (Fig. 384). The gabions are sometimes surmounted, or *crowned*, with 6-feet fascines to improve the cover, but usually with one course of sand-bags laid as "headers."

495. The detachment for the kneeling sap consists of one non-commissioned officer and eight sappers, as in deep sap. The reliefs are managed in precisely the same way, except that the waiting rank relieves after the placing of four gabions —*i.e.*, 8 feet of advance; and Nos. I. and II. change with III. and IV. when half-way through the task—*i.e.*, after placing two gabions.

Each sapper has a sap shield. They work at 5 feet intervals to allow sufficient room.

Fig. 381 shows the profile of the finished sap.

No. I., who works kneeling, excavates a trench 18 inches wide and deep, throwing the earth into the gabion next the sap roller, and leaving a berm of 18 inches. He then loosens as much earth as he can within the limits of his trench, in readiness for filling the second gabion. This done, the sap roller is pushed forward by Nos. II. and III. with long sap forks, while No. I. inserts a gabion in the interval which the sap roller leaves,† and the shields are moved forward as simultaneously as possible, about 2 feet. No. I. fills this gabion as quickly as possible, and loosens the earth up to the sap roller.

No. II., kneeling, widens the trench 20 inches.

No. III. deepens No. II.'s trench 18 inches. No. IV. widens the trench 10 inches. Both Nos. III. and IV. work standing.

The waiting rank keeps up the supply of gabions.

The rate of advance of kneeling sap varies from 6 to 12 feet per hour, according to the soil.

The sap is widened, and if necessary deepened, by infantry in two reliefs, extended as in common trench work.

496. The detachment for *standing sap* consists of one non-commissioned officer and six sappers, three of whom work at a time.

They follow at 5 feet intervals as in kneeling sap, and have all the same task to do—viz., an excavation 18 inches wide and 3 feet deep.

The waiting rank relieves after three gabions have been placed and filled;

* The curved ends of the two front shields are to the front; those of the two rear ones to the rear.

† This should be done with a short sap fork to avoid unnecessary exposure.

the numbers at work further change rounds after each gabion has been placed and filled, No. I. becoming III., II. becoming I., and III., II.

Fig. 383 gives the profile of the finished sap, showing the tasks. All work standing.

When shields are not available, sand-bags* are used for covering the junctions, as in Fig. 384, arranged as follows:—Two three-quarters filled, between the sap roller and first gabion, and similarly two at each junction for about 10 feet back; in addition, the front gabion until filled has four half-filled sand-bags against it which latter, as well as the two close to the sap roller, must be removed by No. I. before the roller is pushed forward, to enable the next gabion to be placed.

The rate of this sap is 4 to 8 feet an hour, according to the soil.

CHAPTER XII.

MILITARY BRIDGES.

MILITARY BRIDGES *defined: their component parts.* WEIGHT OF TROOPS *brought on bridges.* GENERAL RULES *for bridge-making.* PRECAUTIONS *in crossing bridges.* KNOTS *and* LASHINGS *useful in bridging.* TRESTLE BRIDGES: *how made; varieties of trestles.* PILE BRIDGES: *how to drive piles, to form piers and bridges of piles.* SERVICE PONTOON BRIDGE: *general description, methods of forming it.* BOAT BRIDGES: *usual arrangement, precautions to be taken.* CASK BRIDGES: *formation of barrel piers and of cask-rafts and bridges.* TIMBER RAFT BRIDGES: *formation of; examples by Russians over Danube.* FLYING *or* SWINGING BRIDGES: *principle of motion; three methods of working.* BRIDGES WITH LADDERS: *two examples of.* TRUSSED PORTABLE BEAMS *for bridging purposes.* FRAME BRIDGES: *general rules for. Detailed description of construction of* SINGLE LOCK, DOUBLE LOCK, *and* SINGLE SLING *Frame Bridges.*

ADDENDA:—*Calculations for military bridges with reference to buoyancy and strength of beams, with examples. Details of the duties, &c., suitable for working parties of sixteen men in forming*—(1) SINGLE LOCK; (2) DOUBLE LOCK; (3) TRESTLE BRIDGE, *by "booming out," and* (4) PIERS OF CASKS; *and, with eight men*—LADDER BRIDGES: *two kinds of.*

497. Any bridge which can be quickly put together, and the materials of which can be transported and carried with an army, may be termed a ***Military Bridge.***

Bridges used for crossing streams or chasms will vary, according to the nature of the obstacle to be bridged and the materials available for the work, to a very great extent; but in all cases where a stream is sufficiently broad to prevent beams being laid from bank to bank, a structure of a more or less complicated nature will be required.

In whatever manner military bridges are formed, *time* is usually a principal

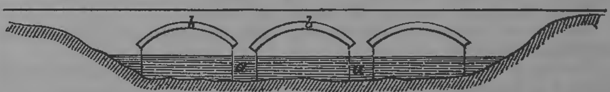


FIG. 385.

object, and every means should be taken, by a proper distribution of men and materials, to construct them as quickly as possible.

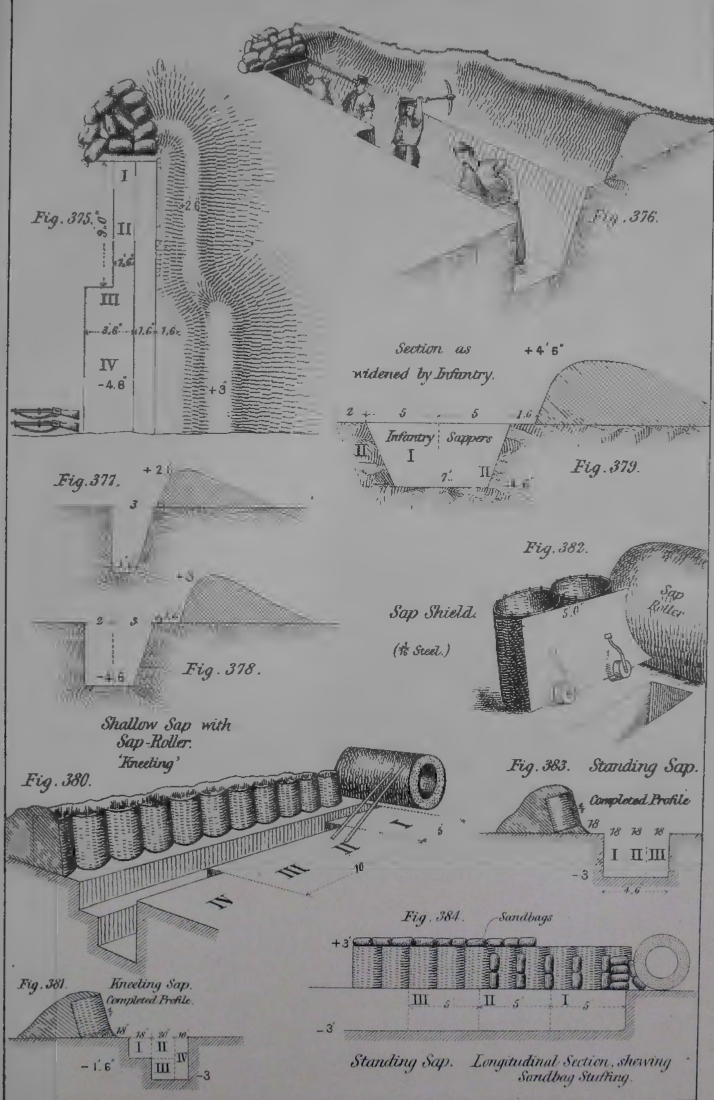
The component parts of an ordinary masonry bridge are—

1st. The *Piers* (*a a*, Fig. 385).

2nd. The *Arches* (*b b*), supported by the piers.

* Sap faggots (short 3-feet fascines) may sometimes be used instead of sand-bags.

SINGLE DEEP SAP.



3rd. The *Roadway*, supported by the arches. And in a military bridge a method somewhat similar is pursued, in order to be able to carry a roadway.

1st. *The Piers.*—These, in a military bridge, are made in one of two general methods: either they rest on the bed of the river, as in trestle or pile bridges, which are termed *fixed bridges* (see Figs. 426, 427*a*, Plate XLVIII., in advance), or they are composed of floating bodies (having sufficient buoyancy to carry the superstructure and the weights required to pass over), which can be made in a variety of ways—as, for instance, with rafts of timber (Figs. 450, 451, Plate LI.), with empty casks connected together in proper number (Figs. 452-3-4, Plate LII.), with boats (Figs. 441-2-3, Plate LI.), or with regular pontoons (Plate XLIX.).

2nd. *The Arches.*—These, in a military bridge are represented by strong beams termed *baulks* or *road bearers*, laid from pier to pier, and therefore running in the direction of the roadway. In certain cases chains or ropes may be substituted for baulks.

3rd. *The Roadway.* This is formed of a flooring of planks, termed *Chesses*, laid across the baulks, and therefore at right angles to the line of roadway. The roadway should in all cases be finished by securing a riband along each side (Fig. 270, p. 93), for the twofold object of stiffening the bridge, and of acting as a kerb, thus preventing the wheels of carriages from slipping over the side.

498. The following are the maximum live loads that can be brought on to a bridge in the passage of troops of various kinds, guns, &c. (extracted from "*Instruction in Military Engineering*"):—

1. Infantry, in marching order, average 200 lbs. per man; and when in file, or in fours, at proper intervals, cause a load of 222 lbs., or about 2 cwt. per lineal foot of roadway.

2. Infantry, in marching order, in file, when crowded by a check, cause a load of 280 lbs., or $2\frac{1}{2}$ cwt. per lineal foot of roadway.

3. Infantry, in marching order, in fours, when crowded by a check, cause a load of 560 lbs., or 5 cwt. per lineal foot of roadway.

4. Infantry, in marching order, when crowded in a disorganized mass, may cause a load of 100 lbs. per square foot of standing room.

5. Unarmed men average 160 lbs. per man, and, when crowded in a disorganized mass, may cause a load of 133 lbs. per square foot of standing room.

6. Cavalry, in marching order, in file, each man and horse together weighing about 1,400 lbs., and occupying about 12 lineal feet of the bridge, cause a load of 116 lbs. or about 1 cwt. per lineal foot of roadway.

7. Cavalry, in marching order, in file, when crowded by a check, cause a load of 189 lbs. per lineal foot of roadway.

8. Cavalry, in marching order, in half-sections, cause a load of 232 lbs., or about 2 cwt. per lineal foot of roadway.

9. Cavalry, in marching order, in half-sections, when crowded by a check, cause a load of about 378 lbs. per lineal foot of roadway.

10. Elephants cannot be made to crowd together. When laden with baggage, an elephant occupies a space of about 99 square feet (11′ × 9′). Their average weight, including their load of 13 cwt., may be taken as 72 cwt., of which $\frac{4}{10}$ths is borne on the hind-legs, which are $6\frac{1}{2}$ feet from the fore-legs. In calculation, it must be assumed that a weight of 44 cwt. may be brought on to one foot of an elephant.

11. Elephants unloaded occupy a space of about 55 square feet (11′ × 5′). The weight of an elephant harnessed into the shafts of a gun may be taken as 66 cwt.; his hind legs are $5\frac{1}{2}$ feet and those of the leader $22\frac{1}{2}$ feet from the axle of the limber.

12. Camels, when loaded with baggage, occupy a space of about 70 square feet (10′ × 7′). Their average weight, including their load of $4\frac{1}{2}$ cwt., may be taken as 15 cwt., of which one-third is borne on the hind legs, which are about $4\frac{1}{2}$ feet from the fore legs. In calculation, it must be assumed that a weight of 10 cwt. may be brought on to one foot of a camel.

13. Pack bullocks, such as are used in India, when loaded with baggage occupy a space of about 13½ square feet (5′ × 2¾′). Their average weight, including their load of 1½ cwt., may be taken as 5½ cwt., of which one-third is borne on the hind legs, which are 3½ feet from the fore legs. In calculation, it must be assumed that a weight of 3½ cwt. may be brought on to one foot of a pack bullock.

14. Cattle for commissariat purposes average about 4 cwt. each, and when crowded occupy a space of about 9 square feet of standing room.

15. The following Table gives the weights, &c., of gun, and other military carriages fully loaded for travelling :—

Description of Gun, &c.	Weight on the Wheels.				Length from centre to centre of bearings of Fore and Hind Wheels.		Width of Wheel Track.*	
	Fore.		Hind.					
	cwt.	qrs.	cwt.	qrs.	ft.	in.	ft.	in.
64-pr. Gun, M.L.R.	22	0	83	3	10	4	5	2
40-pr. ,, ,, ...	23	2	47	1	10	1	5	2
25-pr. ,, ,, ...	15	1	30	2	8	10	5	2
16-pr. ,, ,, ...	16	2	25	0	8	10	5	2
9-pr. ,, ,, ...	16	0	19	2	8	10	5	2
G. S. Forge or Store Wagon ...	26	3	34	1	6	0	5	2
Pontoon Wagon	15	0	24	0	10	0	5	10
Wire Wagon	15	3	22	3	7	4	5	10
Small-arm Ammunition Cart ...	—		19	0	—		5	2

499. The following are some of the general rules to be borne in mind when constructing military bridges :—

1. A roadway 8 feet wide *in the clear* will admit of the passage of infantry 4 deep, and of all descriptions of military wagons in one direction, but 9 feet is a preferable width. The width of a double roadway should not be less than 16 feet.

2. The width between the handrails should not be less than 9 feet for an ordinary bridge; this width should be increased to 10 feet for camels, and to 12 feet if elephants have to cross over.

3. The headway for ordinary military bridges should not be less than 9 feet for military wagons or for cavalry, 11 feet for camels, and 15 feet for elephants.

4. Ramps at the end of a bridge, if intended for artillery, should not be steeper than 1 in 7.

5. In preparing boats to act as pontoons, the baulks or road bearers should not be allowed to bring the weight on to the gunnels of the boats, as the latter would thereby be racked or injured. A saddle should be used with a bearing on the keel of the boat.

6. Casks bear grounding on mud better than boats, few of which will stand the weight of a movable load when grounded.

7. With timber rafts, the ends of the timbers particularly, and if possible the whole of them, should be tarred or painted, to prevent their being water-logged.

8. With open boats, *ordinary* loads, as infantry in fours crowded, or field guns, should not immerse the vessel deeper than within 1 foot of the gunnel; and *extraordinary* loads, such as siege guns, or infantry in marching order, crowded together in a disorganized mass, should not immerse it deeper than within 6 inches of the lowest part of the gunnel. With closed vessels, nine-tenths of the actual buoyancy may be considered available.

9. The waterway between the supports should never be less, and should, if

* The points of the axletree arms project in all cases about 6¼ inches on either side beyond the wheel track.

possible, be more than the width of those supports. The bays of military bridges generally run from 10 feet to 15 feet in length.

10. The supports of a floating bridge (boats, pontoons, &c.) should be at least twice as long as the width of the roadway, unless the buoyancy is much in excess of what is required. This is desirable in order to prevent the bridge swaying.

500. When troops are crossing over pontoon or other temporary bridges, the following rules (extracted from the "*Field Exercise*") are to be observed :—

When large bodies of troops have to pass over a river, and circumstances permit, three bridges will be made—one for infantry, one for cavalry, and a third for artillery and wagons* which accompany the force. Columns of infantry, artillery, wagons, and cavalry should not be allowed to be mixed together in passing over a bridge.

Infantry *must* break step, and all music cease. Files and sections must not be closed up. They may move, if required, at the double, provided they do not keep step.

Cavalry will, as a rule, cross in file, a steady horse leading, but never faster than a walk ; the trot is strictly forbidden. If there be any hurry, they may be passed over in "half-sections," two abreast.

Wheel carriages of all kinds, including field artillery and artillery of position up to the 40-pr. rifled gun, with trained horses, are to cross full horsed ; with unsteady horses, carriages must be passed over by hand. Taking out the lead horses, and crossing with the wheel horses only, is strictly forbidden.

Cattle being liable to take fright, should be driven over in small numbers at a time, the bridge being given up to them entirely for the time of their passage.

Halting on a bridge is to be avoided. If it be absolutely necessary to halt on a pontoon (or other floating) bridge, gun-wheels must rest as nearly as possible midway between two boats. Artillery should cross at increased intervals. If the bridge sway, so as to become very unsteady, the column must be halted, and not allowed to resume its movement until the swaying has ceased.

If heavy guns or traction engines have to be passed over, special arrangements will be made.

These rules apply to all military suspension, spar, and floating bridges.

Officers will incur grave responsibility if they cross a bridge otherwise than in the way recommended by the Royal Engineer Officer in charge.

Knotting (Plate XLVI.), and Lashing Spars, &c. (Plate XLVII.)

501. The size of a rope is denoted by its circumference in inches, and its length is always given in fathoms. Rope is either white or tarred, containing three or more strands ; and, up to the size of five-inch rope, is made up in coils. The hemp is first spun into *yarns* or *threads*, each of which is supposed to be capable of withstanding a strain of from 70 to 100 lbs. Several yarns spun together form *strands*. Three or four strands laid up together form *hawser-laid rope*, while three three-stranded ropes laid up together form *cable-laid rope*. Yarns are spun right-handed, and the strands spun from them laid up right-handed or left-handed, according as the rope is intended to be left-handed or right-handed. Threads twisted up moderately taut, and seldom exceeding nine in number, form spunyarn.

When a rope is passed through a block it is said to be *rove* ; if one end is made fast, that end is called the *standing part*, the other end the *running end*, and the end of the rope to which the power is applied, the *fall*. The general rule for coiling down rope is, for right-handed rope, as in Fig. 386a, with the sun, and left-handed rope against the sun.

* This does not apply to ambulance wagons, &c., accompanying regiments.

502. "*Thumb or overhand knot.*"—Grasping the end of the rope with the right hand, and the standing part in the left, pass the end of the rope over the standing part, up through the bight thus formed, haul taut, and the knot is complete. This is the simplest kind of knot, and is used to prevent ropes running through blocks when rove, &c. (Fig. 386.)

503. "*Figure of* 8 *knot.*"—Holding the rope as described in the last paragraph, pass the end of the rope under, round, and over the standing part, then upwards through the bight thus formed. This knot is used for much the same purpose as the last. (Fig. 387.)

504. "*Reef knot*" (Fig. 388).—Holding one end in each hand, ends to the front, lay the ends of the two ropes to be joined across one another, the left hand rope over the right, and take it once completely round that held in the right hand. Turn the original left-hand end back in the direction of and alongside its standing part, and take the original right-hand end over the double, up through the loop, and haul taut. The standing and running parts of each rope must pass through the loop of the other part in the same direction—*i.e.*, from above downwards, or *vice versâ;* if they pass in the opposite direction, as in Fig. 389, the knot is what is termed a *granny*, and when tightened up cannot be undone with the same ease that a reef knot can. A reef knot can be upset, and the ends pulled out, by taking one end of the rope and its standing part, and pulling them in opposite directions.

505. "*Clove hitch*" (Figs. 390-1-2).—This is the knot most generally useful, and should be practised in various positions. It really is nothing more than two half-hitches.

Make two loops with the running end of the rope, as in Fig. 390, place the loop last made over the other one, as in Fig. 391, and slip the double loop so formed over the end of the spar, &c., as in Fig. 392.

If the knot is to be made round a spar, without slipping it over the end thereof, pass the end over and round the spar, and bring it up to the left of the standing part, and again down and round the spar to the *right* of the first turn, and bring the end up between the spar, the last turn, and the standing part.

When used in lashing spars, the end should be twisted round the standing part, as in Fig. 392.

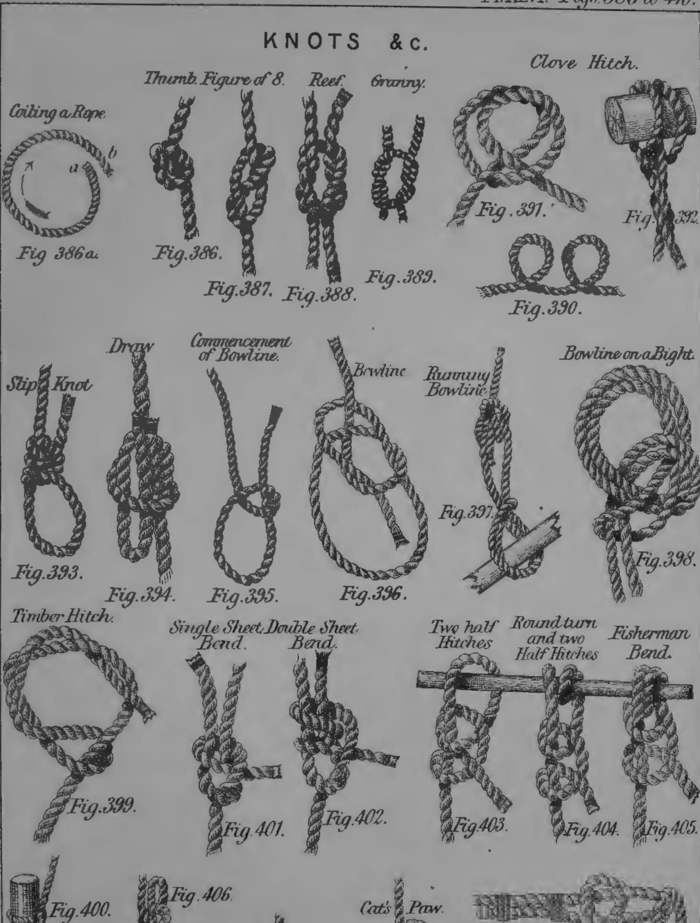
When used for securing the guys to sheers, &c., it should be made with a long end, which should then be formed into two half-hitches round the standing part, and secured to it with spunyarn.

506. "*Slip knot*" (Fig. 393).—Take a bight on the end of a rope, and grasp it in the left hand, the bight towards the right. With the end take four turns round the double of the bight, working from left to right, and pass the end through these four turns next to the standing part, and haul taut.

507. "*Draw knot*" (Fig. 394).—This knot is the same as a reef knot, with the exception that a double of the original left-hand end is laid alongside its own standing part, thus forming a loop, and the right-hand side is taken over the double, and the loop formed by the double, as in the above knot.

508. "*Bowline*" (Figs. 395, 396).—Holding the standing part of the rope in the left hand, with the right hand lay the end over the standing part pointing to the left. Keeping the end in place with the right hand, make a loop with the standing part over the end, as in Fig. 395, pass the end under the standing part, and finally down through the loop previously made, and haul taut the end and the double of the knot together.

509. "*Running bowline.*"—A running bowline (Fig. 397) can be formed round a spar, slipped down, and tightened at any point. To make it, take the coil of the rope in the left hand, pass the running end round the spar from left to right, and draw it back with the right hand as far as required. Still holding the end in the right hand, take the standing part in the same hand, pass the left hand under the standing part, and with the finger and thumb seize the running part of the rope


KNOTS &c.
Coiling a Rope.
a
b
Fig 386a.
Thumb. Figure of 8.
Fig. 386.
Fig. 387.
Reef.
Fig. 388.
Granny.
Fig. 389.
Clove Hitch.
Fig. 391.
Fig. 392.
Fig. 390.
Slip Knot
Fig. 393.
Draw
Fig. 394.
Commencement of Bowline.
Fig. 395.
Bowline
Fig. 396.
Running Bowline
Fig. 397.
Bowline on a Bight.
Fig. 398.
Timber Hitch.
Fig. 399.
Single Sheet Bend.
Fig. 401.
Double Sheet Bend.
Fig. 402.
Two half Hitches
Fig. 403.
Round turn and two Half Hitches
Fig. 404.
Fisherman Bend.
Fig. 405.
Fig. 400.
Timber Hitch applied
Fig. 406.
Sheepshank
Fig. 407.
Cat's Paw.
Cat's Paw.
Fig. 408.
Mousing
Hawser Bend.
Fig. 409.
Fig. 410.
Carrick Bend.

close to the spar. Draw it underneath the standing part from right to left and up, and at that point make a bowline knot on it with the running end. The knot is then run through the loop.

510. "*Bowline on a bight*" (Fig. 398).—Double the rope, and lay the loop, held in the right hand, over the two ends, held in the left hand. With the left hand make a loop over the doubled end, and opening out the doubled end, bring it upwards over the *whole* of the knot, and haul the double taut.

511. "*Timber hitch*" (Figs. 399, 400).—Pass the end of the rope over and round the spar, &c., and round its own standing part close to the spar. Then twist it two or three times back round *itself*, and haul the fall taut, thus jamming the twisted end against the spar. This knot can be easily undone when the strain is taken off the fall, and is found to be very secure for lifting spars, &c., as when well made it will not slip.

512. "*Single sheet-bend*" (Fig. 401).—Take a bight or double at one end of a rope, holding it in the left hand, and pass the end of the other rope held in the right hand up through this bight, down on one side, under and up over the bight, and under its own standing end; it is used for joining two anchor cables together.

513. "*Double sheet-bend*" (Fig. 402).—When greater security is required, a double sheet bend is used, in which the running end is passed twice round the bight and under its own standing end each time.

514. "*Two half-hitches*" (Fig. 403).—With the end of the rope in the right hand, and the standing part in the left, pass the end of the rope round its standing part, and up through the bight, thus forming one half-hitch; two of these alongside one another complete the knot. In Fig. 403 this knot is represented on the standing part of a rope passed round and made fast to a spar, but it should never be used for hoisting a spar. The end may be lashed down to the standing part by a piece of spunyarn, which adds to its security, and prevents the end from slipping.

515. "*Round turn and two half-hitches*" (Fig. 404).—This knot is the same as the last, with the exception that a complete turn is taken round the spar or other object to which the rope is to be fastened, and the half-hitches taken afterwards round the standing part. This knot is sometimes called a *rolling bend.*

516. "*Fisherman's bend*" (Fig. 405).—Two complete turns are taken round the spar or other object to which the rope is to be fastened, and the end passed over the standing part, through the two turns next the spar, over its own part, thus forming one half-hitch, and the second part taken round the standing part alone. It is used in pontooning to fasten the cables to the rings of the anchors.

517. "*Sheepshank*" (Fig. 406).—This knot is used for shortening a rope, the ends of which are made fast. The rope is laid up in three parts, and a hitch taken over each bight with the standing and running parts respectively of the rope, and jammed taut.

518. "*Catspaw*" (Figs. 407, 408).—Form two equal bights as in Fig. 407; take one in each hand, and roll them over the standing part till surrounded by three turns of the standing part, then hook the block into both loops.

519. "*Hawser bend*" (Fig. 409).—Make a bight at the end of one of the hawsers, take a half-hitch with the running end round the standing part, lash them together just beyond the hitch, and seize the end to the standing part; pass the end of the other hawser through the loop so formed, take a half-hitch round its own standing part, and lash as before.

520. "*Carrick bend*" (Fig. 410).—This knot is used for fastening the four guys to a derrick.

521. *To whip the end of a rope.*—Rope ends are whipped with twine called *whipping*, to prevent their strands becoming unlaid. Lay the end of the whipping along the rope, with its point towards the end, and take a turn round it and the rope. Continue the turns until within three turns of the point at which the whipping is to cease, and there make a long loop on the whipping towards the end of the rope, the end upwards; continue the whipping for three turns more, pull them tight by means of the end, and cut off the end close to the whipping.

The methods of making the knots given above appear to be the simplest for purposes of instruction; there are, however, other ways which will speedily suggest themselves to men in practice.

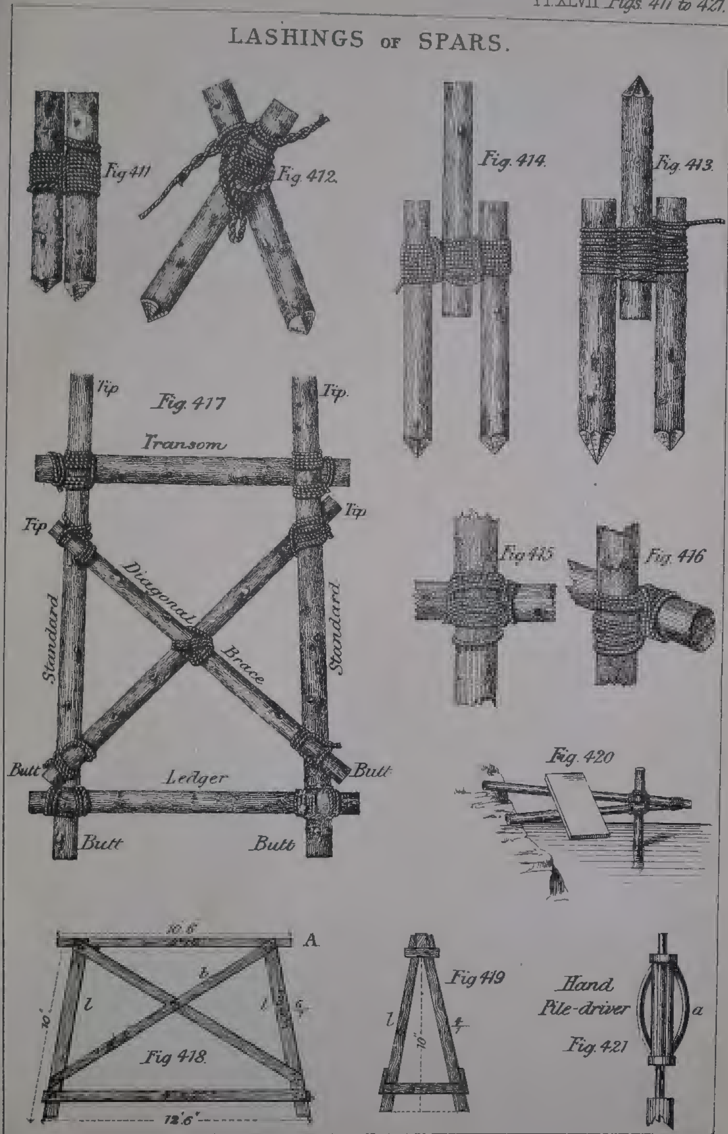
522. *To form a pair of sheers* (Plate XLVII.).—The two spars for the sheers, of equal length, are laid alongside each other, with their butts together on the ground, the parts below where the lashing is to be resting on a piece of skidding, or a short spar. A clove hitch is then made round one spar, and the lashing taken loosely eight or nine times round the two spars, above it, without riding. A couple of frapping turns are then taken between the spars, round the lashing, and finished off with a clove hitch above the round turns on the other spar. It will then appear as in Fig. 411, Plate XLVII. The butts of the spars are then opened out, and a sling passed over the fork of the spars to which the block is hooked or lashed. Fore and back guys are then made fast with clove hitches so arranged as to draw their heads together when the strain comes on them, as in Fig. 412, foot-ropes are secured to the butts of the spars and to pickets, and the sheers are ready for raising. If the tackle be heavy, it need not be hooked on at first, but a whip must be secured near the top of one of the spars, by which it can be raised afterwards. In securing the rope of the whip to the block, for this purpose, it should be bent on to the eye in the strop of the block, and not to the hook. The block can then be raised to its proper height, and a man can hook it into the two parts of the sling, which he would find very difficult if the whip were made fast to the hook itself.

523. *To lash three spars together to form a gyn or tripod trestle.*—To form a gyn or tripod trestle, the distance from the butts at which the centre of the lashing is to be is marked on each spar. Two of the spars are then laid parallel to one another, rather farther apart than their own diameter, with their tips resting on a piece of skidding, and the third spar is laid between them with its butt in the opposite direction, so that the marks on the three spars may be in line. A clove hitch is then made on one spar, and the lashing taken over and under the three spars loosely eight or nine times: the lashing will then appear as in Fig. 413. A couple of frapping turns are then taken between each pair of spars in succession, round the lashing, and finished off with a clove hitch on one of the spars: the lashing will then appear as in Fig. 414. A sling is then passed over the lashing, and the gyn is ready for raising.

524. *To lash a transom to an upright spar.*—The mode of lashing a transom to an upright is shown in Figs. 415, 416; in the description the transom is supposed to be in front of the upright. A clove hitch is made round the upright below the position of the transom, the lashing brought under the transom, up in front of it, horizontally behind the upright, down in front of the transom, and back behind the upright below the clove hitch, and so on following round, keeping outside of previous turns on one spar, and inside those on the other, and not riding over the turns already made. Four turns or more will be required. A couple of frapping turns are then taken between the spars round the lashing, binding the whole firmly together, and the lashing is finished off with a clove hitch, either round one of the spars or any part of the lashing through which the rope can be passed. The lashing must be well beaten with a handspike or pick handle to tighten it up.

Descriptions of various Military Bridges.

525. Trestle Bridges.—These are applicable to shallow rivers whose beds are sound and firm, and which are not subject to sudden floods during the periods


LASHINGS OF SPARS.
Fig 411
Fig. 412.
Fig. 414.
Fig. 413.
Fig. 417
Tip
Tip.
Transom
Tip
Tip
Diagonal
Brace
Standard
Standard
Butt
Butt
Ledger
Butt
Butt
Fig. 415
Fig. 416
Fig. 420
10'6"
A.
l
l
l
10'
Fig 418.
12'6"
Fig 419
l
10"
Hand
Pile-driver
a
Fig. 421

within which a sure communication across them is required; but they are unsuitable for deep, muddy, and fluctuating streams.

Trestles have the advantages of requiring (compared with other bridges) but little timber, and of being portable: for materials to make a good trestle may be carried by one mule; and if these be previously fashioned, fitted, and the parts numbered, the trestles may be soon put together. Trestles so prepared should be fastened with iron bolts and keys; but if made on the spot, there to remain, wooden pins may be used.

Figs. 418, 419 are a side and end view of a trestle of the usual construction when put together with nails. The capping plate, or head beam (A), should be a stout beam 8″ square, and will vary in length (according to the required width of roadway) from 10 to 16 feet.

The legs (*l*, *l*), 6″ or 7″ square, should be notched to fit under the head beam, so as to support it well, and should make an angle with one another, so as to rest on a base about half their height, as in the end view, and they should incline longitudinally, but to a less extent, as in the side view. The braces (*b*, *b*), about 6″ by 3″, give great strength to the trestle.

When a trestle of the foregoing description is only 4′ or 5′ in height, the braces shown in the side view should meet one another under the middle of the head beam.

526. A two-legged trestle, Fig. 422, Plate XLVIII., may be used in streams 6 feet deep and running with a velocity of 5 feet per second; or in deeper streams if the velocity of the current be less. They are suitable for any kind of hard bottom. The materials required are—

1 transom, 10 to 14 feet long, and 5¾″ to 7″ in diameter; or 2 transoms may be used, as in sketch *a*.
2 legs 4 feet longer than the trestle is high, 4½″ to 6″ diameter.
2 diagonals, 3½″ to 4½″ in diameter.
1 ledger, 3″ to 6″.
6 lashings of 1½″ rope, 5 fathoms long.
3 ,, ,, 2½ ,,

Timber of the proper scantling being obtained and cut, the pieces are laid on the ground and lashed as shown in the figure. Four men should make this trestle in one hour.

527. A four-legged trestle of the form shown in Fig. 423 may be used in still water, where a greater length of leg than 12 feet is not required, or in running streams where the water is not more than 3 feet deep, or the velocity greater than 3 feet per second. It can only be used on an even bottom. The following materials are required:—

2 transoms, 10 to 14 feet long; scantling 5″ to 6″.
4 legs, scantling 3¾″ to 4¾″.
4 diagonals, scantling 3″ to 3½″.
4 ledgers ,, 2½″ to 3″.
12 lashings, 1½″ rope, 5 fathoms long.
10 ,, ,, 2½ ,,
2 spike nails, 8″.
4 iron dogs.

Timber of the requisite size being obtained, each frame is formed separately on the ground, in the same manner as the frames of the Single Lock Bridge. They are then raised and locked together, and the end ledges lashed on. Six men should make this trestle in a little over one hour. It is cumbersome to adjust when made.

528. Tripod trestles of the form shown in Fig. 424 are particularly useful for military bridges, as the level of the roadway can be readjusted if the water rises, or if one tripod sinks into the mud more than the other. The legs of each tripod should be so adjusted that their point of crossing may be exactly over the centre of gravity of the triangle which forms the base of the tripods. The transoms may be supported, if necessary, on the tops. The following materials are required :—

1 transom, 14 feet long, 7" to 8" diameter.
6 legs, 3" to 5" diameter.
4 cross-bearers, 4 to 6 feet long and 3" to 3½" diameter.
4 stakes, 2 feet long, 2" diameter.
6 ledgers, 6 ,, 1¾" to 2½" diameter.
12 lashings, 1½" rope, 5 fathoms long.
6 ,, ,, 2½ ,,

529. Before making a trestle bridge, a section of the river should be made in order to determine the lengths of the legs of the various trestles, which should be arranged on the bank in the order required, the first trestle being nearest to the water. After a trestle has been got into position, two additional legs may be fixed by driving piles into the bed of the river, one on each side of the trestle, and bolting them to the head beam.

In forming a trestle bridge, the trestles may be got into position in various ways—

(*a.*) By hand, if the water is shallow, and the weather not severe.*

(*b.*) By boats or rafts, if such are available.

(*c.*) By "*booming out*" from one bank towards the opposite one, when it is impracticable, from depth of water or absence of boats, to work in any other manner.

530. The following is an outline† description of the method of "booming out" :—

First lay two *way baulks*, similar to *B*, Fig. 426, with their ends (weighted, if necessary) resting on the bottom of the river, at the place where the trestle is to stand—the distance between the baulks should be a little less than the length of the trestle ; then place the trestle on the inclined plane so formed, as at *b* ; lower it to the bottom, and push the head outwards till the trestle is upright, as shown at *c*. Ascertain that it has a firm bearing on the bottom. The first set of baulks (usually 5 or 6 in number) can then be laid, their shore ends resting on a beam (*a*, Fig. 428) sunk to receive them, as described in Art. 573 ; the planks forming the floor are next laid, and the roadway completed as far as the first trestle. The next trestle would be fixed in position by laying two beams (as *B*, Fig. 426) in an inclined position, resting on the bed of the river and on the first trestle, in a similar manner as before. The fresh trestle would then be laid on the beams, lowered to the bottom, and afterwards placed in its intended position, the baulks and planks being next completed as far as the second trestle. The whole bridge would be constructed in this way, trestle after trestle. As soon as the roadway of planks (chesses) is complete, the beams acting as ribands should be laid on each side and *racked down*, as in Fig. 270, Art. 291. After a trestle is placed, it may be further secured from the action of the current by heaping large stones round its base. This precaution, however, must not be carried to excess, as it contracts the waterway and increases the scour of the stream.

531. Trestle bridges, as before stated, are unsuitable for streams liable to sudden floods (which would probably destroy them), and they have the further disadvantage of not allowing drifting matter (trees, &c., probably sent down stream by an enemy) to pass under the points of support, and of stopping the navigation of the stream.

* In the construction of the trestle bridges over the Beresina, by which the wreck of the French army crossed in their retreat from Moscow, in 1812, no boats could be procured to facilitate the work, and the pontoneers were obliged to remain in the water throughout the whole of the operations, which were carried on during a severe frost.

† For the detail of the drill suitable for this and other bridging operations with a working party of sixteen men (number usually in the working squads at the Royal Military College, Sandhurst), see the end of this chapter.

TRESTLES &c.

Fig. 422. Two legged Trestle

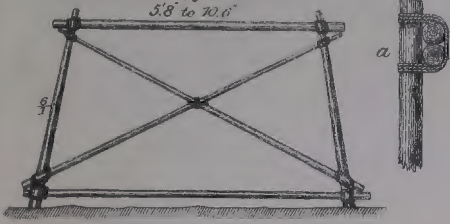


Fig. 423. Four legged Trestle

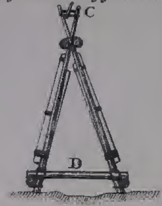


Fig 424
Tripod Trestle

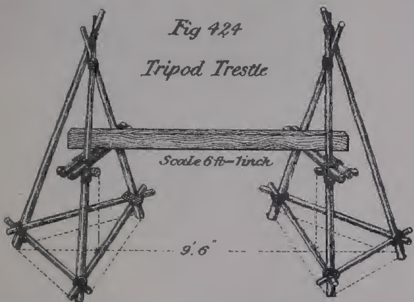
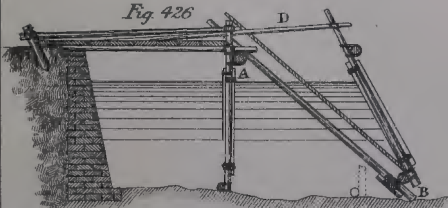


Fig. 425.

Fig. 426



Abutment for Temporary Bridges
Fig 427

Section.

Bridge on Piles.

Fig. 427 (a) Fig 428 (a)

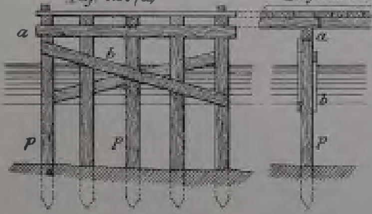
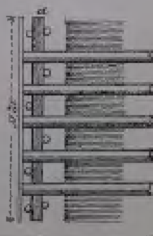


Fig 428
Plan



532. Pile Bridges.—In these bridges the piers are each formed with a row of stout piles (*p*,*p*, Figs. 427*a*, 428*a*) driven by some kind of pile-driver as far as possible into the bed of the river; their tops are then sawn off level with one another in order to receive a cap plate (*a*), which is either bolted to the piles or secured by iron dogs. On this cap plate the baulks are laid in the usual manner, and the roadway formed with planks secured by the usual ribands and rack lashings. Braces (*b*, *b*) should, if the level of the water permit, be added to each pier of piles. The outer piles of each pier should be stouter than the others.

Pile piers should be as far apart as the length of the baulks procurable will admit, and should not be nearer to one another than 10 feet.

Pile bridges are suitable for deep and muddy rivers, and when the communication is required to last for a considerable period.

Piles are also very useful for forming breakwaters to protect bridges in strong currents from the force of the stream, or from anything floating in it, whether by accident or set adrift by an enemy with the view of destroying the bridge. For this purpose three or more piles set in a triangular figure should be driven above each pier (whether of rafts, trestles, or boats), and fastened together by strong cap-pieces, well braced and planked, so as to form a powerful buttress or breakwater, presenting an angle to the current.

Pile bridges are unsuitable equally as trestle bridges for streams liable to sudden floods, and both natures have the objection of not allowing drifting matter to pass under the points of support, as is the case with floating bridges.

533. *To drive the piles.*—When the bridge is intended for light weights, piles 6″ or 7″ in diameter may be used, and driven by hand with heavy mauls, as shown in Fig. 420; and in this way piers may be formed sufficiently strong to bear infantry on a front of two or three files, with open ranks, and not keeping step.

When piles of 8″ in diameter, or upwards, are used for the piers of a bridge, they will require to be driven by some kind of pile-driving machine. When pile-drivers are constructed in the field, the *ram* (or weight used to drive the piles) might be made from an 8″ or 10″ shell filled with lead. The shot or shells of rifled guns would be still better for the purpose, owing to their shape and flat bottom. The shot is suspended by a rope or chain, which is made to pass over a pulley at the head of a couple of standards properly guyed or stayed. A raft of some kind is required for the pile-driver to work upon: its breadth should be such that it can be used *between* two of the piers. Casks, if procurable, are most convenient for the raft.

534. *Hand Pile-driving, Swiss method* (Fig. 421, Plate XLVII.).—A vertical hole is bored in the centre of the head of each pile, truly parallel to the length, to a depth of about one foot, and in this hole is temporarily placed a guide rod of 2″ iron, 6 feet long, up and down which a *monkey* is worked by hand by four men who stand on a platform fixed to the pile.

The monkey (*a*, Fig. 421), weighing 130 lbs., with a hole down its centre, is made of a piece of oak about 9½″ in diameter, 3 feet long, and provided with four iron handles.

Floating Bridges.

535. Pontoon Bridges will be first described under this heading, as they illustrate a military bridge in a form more nearly perfect than other floating bridges.

The general shape of the pontoons used by most nations is that of a flat-bottomed boat, with upright or slightly sloping sides.

The Austrian, Belgian, and Prussian pontoons are open iron boats or bateaux. The French and Italians use open wooden bateaux. The Russians use open canvas pontoons, with a wooden framework, which can be taken to pieces.

SERVICE PONTOON BRIDGE. (Plate XLIX.).

536. The pontoon bridge is formed of pontoons kept at 15 feet central intervals by *baulks* fitting on to *saddles*, which rest on central *saddle beams.*

The number of baulks used is five for the *advanced bridge* (for infantry, cavalry, and field artillery) and nine for the *heavy bridge* (for siege artillery and "steam sappers," a species of traction engine). They (the baulks) support the *chesses*, which are kept in position by a *riband* on each side, racked down by *rack lashings* to the outer baulk, and leaving a clear roadway of 9 feet.

The pontoons were designed so that they should not be immersed to within one foot of the top of their coamings when carrying their ordinary loads of infantry in marching order, in fours crowded at a check, or carriages equal in weight to the 16-pr. gun, weighing 42 cwt.; and so that they should not be immersed to within six inches of the tops of their coamings when carrying extraordinary loads, such as infantry in a disorganized mass, or weights such as the 64-pr. gun and carriage, weighing 99½ cwt.

537. The pontoons are flat-bottomed boats 21′ 7″ long, 5′ 2″ broad, and 2′ 8″ deep amidships, including the coaming 5″ in height. The ends are decked, and the sides are partly decked, the "well" having coamings 5 inches in height. Each pontoon weighs about 800 lbs.; it draws when floating empty 2½ inches, and when in bridge 6 inches: roughly speaking, each inch of immersion gives 500 lbs. of buoyancy.

The pontoon consists of a strong framework, to which are secured the sides and the bottom of thin wood having canvas attached to both sides by india-rubber solution.

Each pontoon is a serviceable boat, capable of containing a considerable number of armed men.

Attached to the framing of each pontoon is a *saddle beam*, over which fits a movable *saddle*, furnished with cleats so arranged that the "baulks" have merely to be placed in between them.

The *baulks* are 15′ 9″ long, 3″ broad, and 6″ deep. They are halved at the ends, where they are strengthened by iron plates at top and bottom. The bottom plates are made with claws at each end; these fit over the saddle, and keep the pontoons at central intervals of 15 feet.

The *chesses* are single planks 10 feet long, 1 foot broad, and 1½ inches thick. The breadth at each end is diminished to facilitate their being laid by hand, and to enable the rack lashings to be passed between two adjoining chesses.

The *ribands* are of the same dimensions as the baulks, and are provided with 14 buttons underneath to fit in the openings at the ends of the chesses.

The buoyancy of the pontoon bridge is sufficient to admit of carriages of 5½ tons weight being passed over it with safety.

538. An unit of the pontoon train consists of—

20 pontoon wagons loaded with pontoons and superstructure.
4 " " " trestles and superstructure.
6 store wagons } (R.E. pattern.)
1 forge wagon }

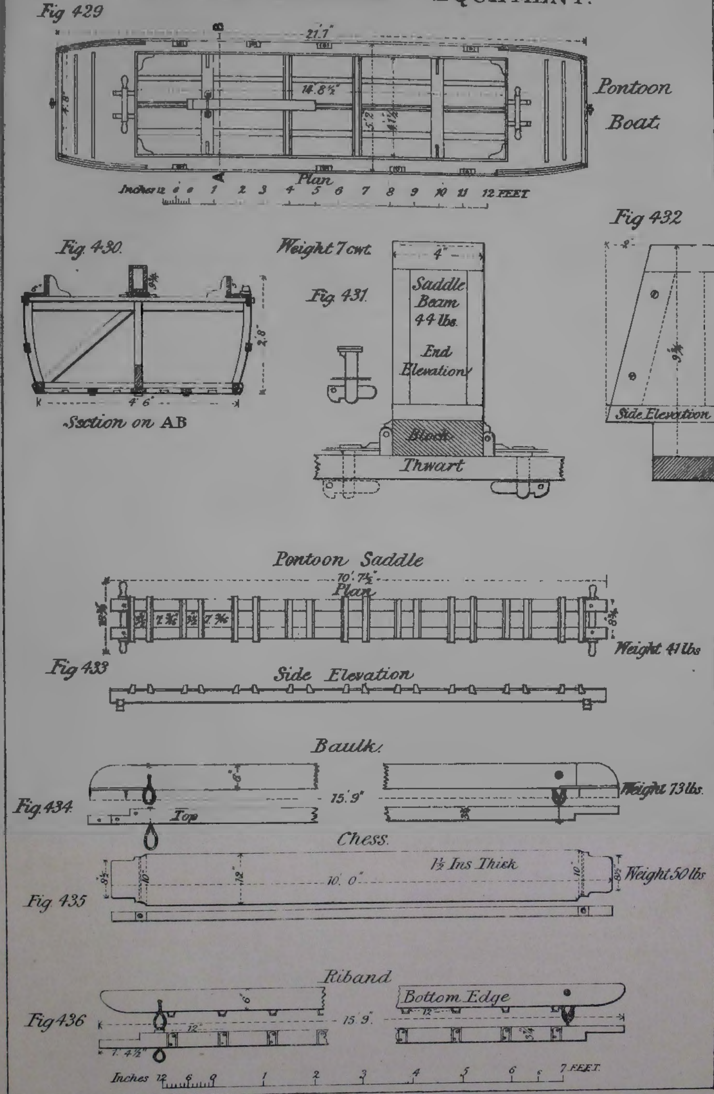
Each of the 20 wagons loaded with pontoons carries (with a few trifling exceptions) the same pontoon stores—viz., 1 pontoon and superstructure for 1 bay (15 feet): it is therefore quite immaterial in what order the wagons are unpacked and the pontoons arranged in bridge.

539. An army in the field is accompanied by a certain amount of portable bridge equipment in the shape of pontoons and trestles.

The proportion for the British Army is one pontoon troop (one unit) for an Army Corps, carrying 100 yards of pontoon bridge and 20 yards of trestle bridge.

Portable bridges of this description, owing to their mobility and rapidity of construction, are too valuable to be left for long in one place: having served for the passage of an army, they should be supplemented by bridges of a more permanent type, and thus set free for further operations in front.

SERVICE PONTOON EQUIPMENT.



SERVICE PONTOON BRIDGE.

prepared for "forming cut."

Fig. 437

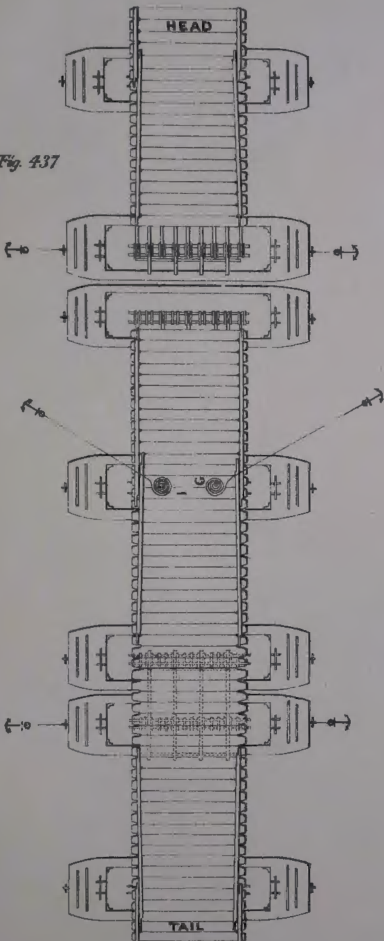


Fig. 439

Cut Baulk

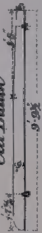


Fig. 438

Frame of cut baulks

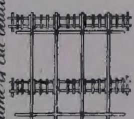


Fig. 440.

540. The bridge may be constructed in either of the following ways:—

(*a.*) By "*booming out*," *i.e.*, by pushing out the pontoons in succession from the shore, the roadway being completed each time from the shore to the nearest pontoon; in this case the shore end of the bridge is the last to be completed. The bridge can be brought on shore by a reverse operation, termed "booming in."

This method is expeditious, and occupies only a short length of the bank of the river; it has the defects of requiring some men to work in the water, the labour of lifting is very great, and the cables require to be constantly shifted while the operation is being carried on, which would be extremely difficult in very rapid streams.

(*b.*) By "*forming up.*" In this case the shore end is first constructed, and the pontoons are warped up to the head of the bridge and anchored in succession.

This is a good method, but is not so expeditious as booming out; none of the men have to work in the water, the cables are secured at once in their final position, and there is no heavy lift; but the superstructure has to be carried to the head instead of to the tail (shore end) of the bridge.

(*c.*) By "*rafts.*" Rafts consisting of two pontoons are first constructed at convenient positions; they are rowed into position for the bridge, and anchored; the roadway is then formed across the intervals between them, either successively or simultaneously.

(*d.*) By "*swinging.*" In this case the whole bridge is formed alongside the shore. The head of the bridge is shoved off, and the current is allowed to swing it into position. Anchors are cast in succession as each portion of the bridge comes into the line of the intended position.

In this manner troops can be thrown across a river in presence of an enemy very rapidly. The bridge would be formed under cover of some kind (behind an island, for instance), then dropped down stream and swung across at the intended position. Troops placed on the bridge before it is swung would be thrown ashore immediately the head of the bridge reached the opposite bank.

541. For bridging purposes, the unit fixed on is a detachment of 1 N.C.O. and 7 men. One detachment can man a boat or a raft. Two detachments form a bridge section. Four detachments form a bridge division, and can in still, narrow waters boom out a bridge after having unpacked the wagons.

542. *Forming Cuts.*—Cuts may be required in pontoon, as in other floating bridges, to allow of traffic passing, or of large floating objects (trees, &c.) being guided through the bridge.

To form a cut, one or more rafts have to be disconnected. These rafts should be fixed on beforehand, and provided with special baulks (Figs. 437-8-9-40, Plate L.). These baulks, which are not halved at the ends, go into the intermediate cleats of the saddles. They are not, like the other baulks, 6″ deep, and can, after the chesses which rest on them have been removed, slide in freely under the superstructure of a bay, as far as their inner cleats. In order to make them slide in together they should be connected by oars or light poles, so as to form a kind of frame.

The pontoons on which the bay, or bays, for the cut rest should be kept about 6″ from the bridge pontoons by breast lines. In "forming cut" these are cast off, and the stream cables are paid out until the raft is well below the bridge. It is then warped up into place behind the bridge.

Plate L. shows the details for forming a cut in a regular pontoon bridge.

The principle can be easily applied to bridges of boats, or of casks, &c.

543. Bridges of Boats.—Bridges are frequently made across rivers which are too rough and broad for ordinary pontoons, by using the boats that can be procured on the river as floating piers; and by connecting them by baulks fastened to a temporary trestle or saddle fixed in each boat; the chesses forming the roadway are laid in the usual manner, and are secured by ribands to the baulks.

The following conditions should be fulfilled, as far as circumstances will permit:—

Boats, constructed to carry cargo, should be used, if available.

Boats of the same size should be used, as they will be equally immersed by equal weights, thereby keeping the roadway as level as possible. With very large boats or barges this precaution is not so necessary, as their buoyancy will be much in excess of what is required to support the heaviest weights likely to pass. Under such circumstances, the intervals should be made as great as the timber procurable for baulks will allow. The boat nearest to the shore at each end should be stronger and more capacious than the others, as it has to withstand the pressure of heavy vehicles descending from the banks to the bridge.

If small boats of different capacities are necessarily used in the same bridge, the intervals between them should be regulated accordingly.

The construction of the bridge should be such as to allow the boats to undulate a little with the swell, as the security of the bridge will thereby be much increased. This will be effected by securing the baulks to a saddle or trestle, the top beam of which rises above the gunwales, as in Figs. **442, 443,** as the boats can then incline considerably to either side without inconvenience to the roadway.

It would be objectionable to lay the baulks on both gunwales of the boats, if much motion in the boats were probable, as such motion would be too much restrained, and would tend to break the baulks and also injure the boats.

It would also be objectionable to lay the baulks so that each baulk rests merely on the nearest gunwales of two adjacent boats, as a heavy weight passing over the bridge would cause the boat to dip or heel very much. This objection, it must however be observed, becomes less in degree as the boats used are large, and hardly applies at all to barges, lighters, and vessels of from twenty to thirty tons or upwards.

The buoyancy of each boat* should be such that the greatest weight to be carried should not immerse it sufficiently to risk its being swamped at the moment of its maximum immersion. A height of 1′ above the surface of the water is the minimum that should be allowed for the gunwale at the moment of its greatest immersion; and to prevent the wash of waves at that time filling the boat, it is a good precaution to cover the boats with a light framework over which canvas is stretched.

In a bridge of boats, each boat is usually anchored head and stern; and the boats are sometimes fastened together by pieces of timber lashed across their ends, or by cables secured thereto, so as to preserve the proper intervals and relieve the baulks from strain.

When large, strong boats are used, the saddle may be formed by placing a stout beam of the proper length, according to the intended width of the roadway, on other beams laid across the boat, as in Fig. 444; but with small boats, the sides of which are usually slight, it will be necessary to support the beam (A, B, Fig. 441) on the keelson.

When constructing a bridge of boats, provision should be made for allowing a portion of it to be quickly withdrawn, in the event of its being necessary to pass vessels or floating timber, &c., through the bridge. See Art. 542, "Forming Cut" in a pontoon bridge.

In a tidal river, alternate boats should point up and down stream.

544. Cask Bridges.—After what has been described in explanation of the construction of pontoon and boat bridges, it will only be necessary to consider casks with respect to their buoyancy, and the manner in which they are usually connected together so as to form the piers of a floating bridge, and the manner in which these are joined together in a bridge.

When collecting casks for bridges, they should be carefully sorted. Large

* For most practical purposes, the buoyancy of a boat may be determined with sufficient accuracy by loading it with shot, men, or other known weights, and observing its immersion.

BOAT BRIDGE &c.

Fig. 444.

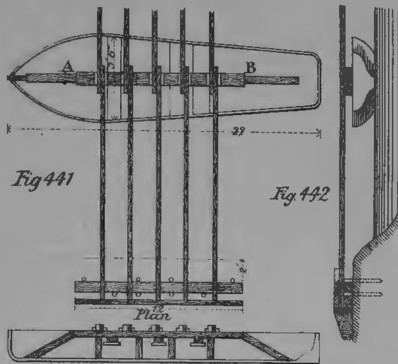


Fig. 441

Fig. 443 Section on A B

MAKE SHIFT ANCHORS

Fig. 445

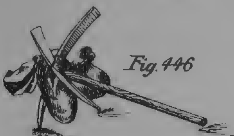


Fig. 446.

RAFT BRIDGE THROWN OVER THE DANUBE IN 1854.

Fig. 450 Scale $\frac{1}{180}$

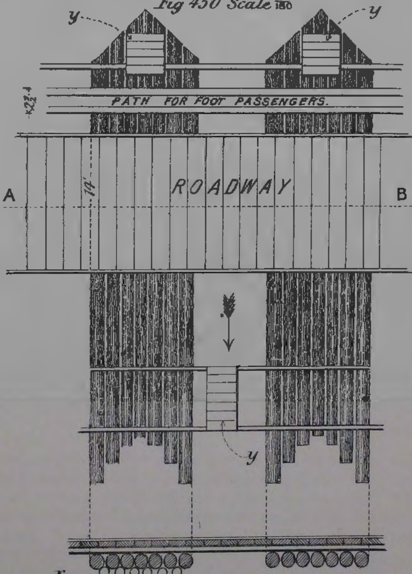


Fig. 451. Section on A B. y y Capstan platforms.

Fig. 447.

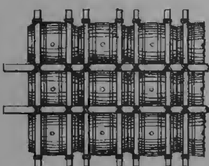
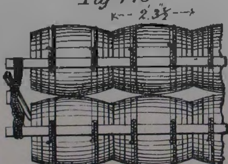


Fig. 448



Section

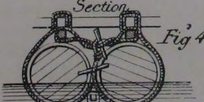


Fig. 449

casks are to be preferred to small ones, because, with them, piers are more easily put together; and with equal buoyancy a pier of large casks will weigh much less than a pier of small ones—a matter of great importance should they require to be transported by land. The casks generally used are 4′ 3″ long, with head diameter 2′ 2″, and bung diameter 2′ 9″; their weight averages 174 lbs. each. Seven of these casks connected together in the manner about to be described form an efficient substitute for a pontoon, each cask having a buoyancy of about 1170 lbs.

545. The following stores are those used with the above-named casks for forming piers and rafts of casks:—

Gunnels, 21 feet long, 4″ × 5″, or 5″ to 6″ round, flatted on one side. The centre of each gunnel should be marked, and marks for the outer baulks made with paint or a saw at distances of 4′ 6″ on each side of the centre mark.

Slings formed of a piece of $2\frac{1}{2}$-inch rope, originally 6 fathoms long, but reduced by making an eye splice, 1 foot long, at one end.

Braces of $1\frac{1}{2}$-inch rope, 3 fathoms long, with a small eye splice at one end, and a "figure of eight" knot about 1 foot 5 inches from the eye.

Tie baulks, 15 feet long, and 3″ to 4″ round or square: the central intervals between the piers being marked by two marks equidistant from the ends.

Tie baulk lashings, 1-inch rope, 20 feet long.

Baulks, 14 feet to 15 feet long, and 5″ in diameter.

Chesses: those for pontoon bridges, or similar ones.

Anchors: those of about 1 cwt. hold well.

Ways, for launching piers, formed of two baulks or side pieces, with curved ends, framed together and provided with three *way ropes* on each side, similar to the braces.

546. The stores required for one pier are as follows—

7 casks.	12 braces.
2 gunnels.	2 breast-lines,
2 slings.	1 boat-hook.

In forming the barrel piers, Figs. 452-3-4, *the casks* are laid out in line with the bungs uppermost, *the gunnels* are placed over the ends of the casks, and *the slings* are then secured under the ends of the casks and to the gunnels.

Between each pair of casks, on each side, *a brace* is secured on the sling, and is then led round the gunnel; the opposite braces are crossed, and secured again on their own side.

The pier is then launched into the water.

The drill for forming piers with seven casks (founded on the pontoon drill) is given in Art. 587 at the end of this chapter: a pier always requires two more men than twice the number of casks to form it: thus 9 casks would require 2 (9 + 1) or 20 men.

547. When small casks only are procurable, they may be formed into piers in a variety of ways. Two methods are given in Plate LI., Fig. 447, and Figs. 448, 449.

In Fig. 447 the casks are first made into small piers, each of 3 casks: these small piers being arranged side by side and touching, are connected together by two baulks on top of their gunnels, and on these the road bearers will rest.

Figs. 448, 449 represent a pier formed of two rows of casks, end to end.

The braces 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 casks are laid two gunnels, 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 gunnels should be less than a bung diameter. The braces are then secured to the gunnels by two round turns and two half-hitches. The four lashings connecting the gunnels are then racked, and finally the two at the ends are secured to the tie baulk by lashings which are racked up.

548. *Cask Bridges.*—The piers formed as described in Art. 546 are connected together, and the bridge formed, as follows (Plate LII., Figs. 455, 456) :—

Across the end of the gunnels the tie baulks are lashed so as to retain the piers at the proper central intervals (10 feet with the piers shown in Figs. 452-3-4, Plate LII.); the baulks can then be laid (for ordinary work these do not need to be lashed).

In Fig. 455 the baulks are shown overlapping, as they rest at each end on the two gunnels of a pier, and so the ribands (which have the same dimensions as the baulks) have to overlap also.

For wheel traffic the ribands should be large and should butt over the centres of the piers.

Rafts made of barrel piers (the number of piers varying according to the requirements) are very useful for conveying heavy stores which cannot be stowed in boats, for bridge-ends, for placing trestles and piles, and also for diving from, &c.

If, however, a raft be kept too long in the water, the ropes will rot, and the raft may break up at any moment.

Cask bridges may be formed from piers by any of the methods described in Art. 540 for pontoon bridges.

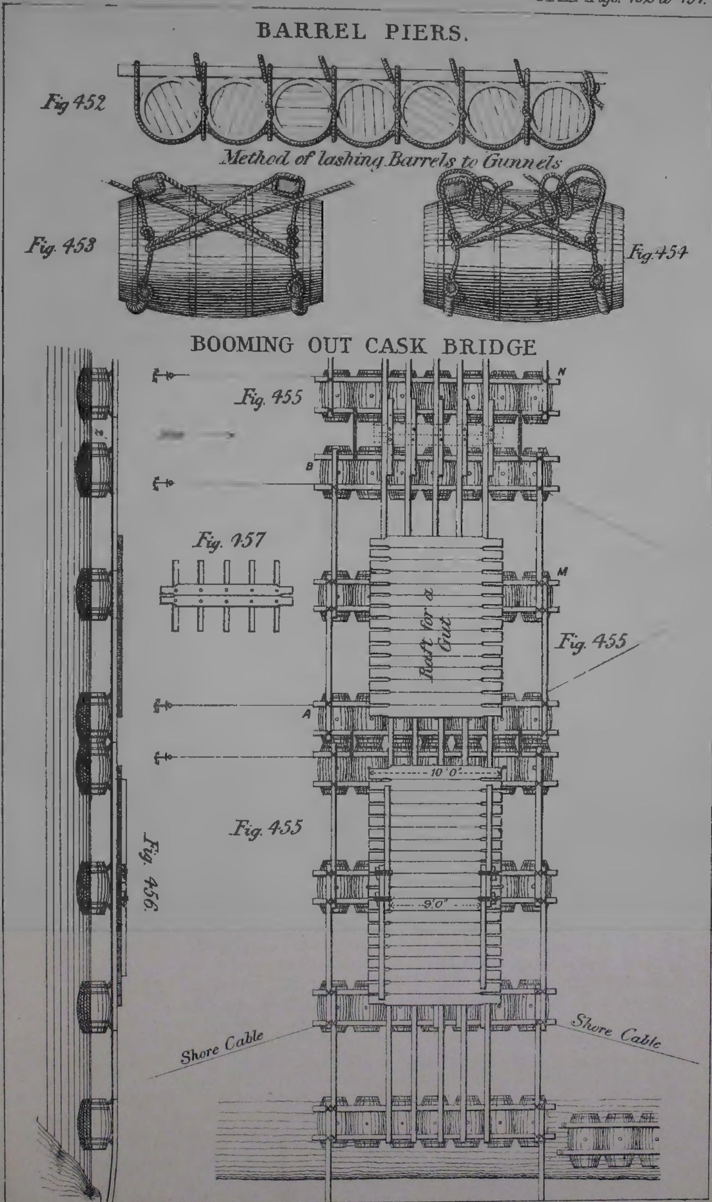
In forming a bridge from rafts, the quickest way, when there are enough piers, is to allow the outer piers of each raft (which may consist of from two to six piers) to touch, as in Fig. 455; otherwise each raft must carry with it the superstructure for one bay.

Fig. 455 gives all the details of a cask bridge, which is, in the illustration, in process of being formed by "booming-out." Near the shore, at the tail end of the bridge, is shown a pier in readiness to be placed in position when the bridge, already formed, is "boomed-out" for the length of one bay of 10 feet.

549. The stores for one pier and 10 feet bay, to carry infantry in fours, crowded, are :—

Detail.	No.	Dimensions.			Weight.
		Length.		Size.	
		ft.	in.		lbs.
Casks	7	4	3	2 ft. 9 in. and 2 ft. 2 in.	1,218
Gunnels	2	21	0	5 in. round	162
Slings	2	36	0	3-in. rope	7
Braces	12	18	0	$1\frac{1}{2}$-in. rope	10
Tie baulks	2	15	0	3-in. round spars... ...	50
,, lashings	8	20	0	1-in. rope	8
Baulks	5	14	0	5 in. round	450 (Baulks and Ribands)
Ribands	2	14	0	5 in. round	
Chesses, or planks ...	10	10	0	$1\frac{1}{2}$ in. × 12 in.	503
Boat hook	1	16	0	... ...	30
Rack sticks	6	1	0	$1\frac{1}{2}$ in. round...	3
Rack lashings	6	6	0	$1\frac{1}{2}$-in. rope	4
Anchors	1	3	10	2 ft. 0 in.	112
Cables	1	180	0	3-in. rope	132
Buoy	1	2	0	10 in. diam....	10
Buoy line	1	60	0	1-in. rope	3
Breast line	1	60	0	1-in. rope	3
Total weight	... ...	...	...	... ...	2,705

549A. *Makeshift Anchors* (Plate LI.).—In bridging operations on a large scale, it is often necessary to improvise temporary anchors to moor the boats, rafts, &c.


BARREL PIERS.
Fig 452
Method of lashing Barrels to Gunnels
Fig. 453
Fig. 454
BOOMING OUT CASK BRIDGE
Fig. 455
N
B
Fig. 457
M
Raft for a Gun
Fig. 455
A
10' 0"
Fig. 455
Fig. 456.
9' 0"
Shore Cable
Shore Cable

An anchor may be made as in Fig. 445, of two picks lashed together in two places, and two other pick-heads fitted over their ends, which are prevented from slipping off by two slight lashings. It is difficult to select picks that will fit firmly together for this anchor.

Another anchor, Fig. 446, consists of one pick, the handle of which is rounded just below the head, and another pick-head driven on the handle at right angles to the first, and wedged there by driving in two spike nails. The holding power of this anchor is much increased by lashing, as in the figure, one or more shells in sand-bags to the head.

Either of the above anchors could be made by a couple of men in fifteen minutes.

550. *Raft Bridges.*—Rafts of timber used as floating piers are resorted to when other kinds of floating piers are not to be procured; but they have the defects of possessing low buoyancy, and (if in the water for any length of time) of being apt to become waterlogged;* they are also comparatively clumsy, being very heavy, and require considerable time in their formation.

At the same time they have these merits—they are able to be put together by inexperienced workmen; they cannot be sunk by hostile fire; and if not disturbed they will last for a considerable time.

Raft bridges of timber are suitable for currents not exceeding 2 to 3 miles an hour, and should not be used in rivers where the current exceeds 4 miles per hour, as beyond this velocity the water will be so much impeded that it will hardly be possible to secure the rafts, which necessarily occupy a considerable portion of the waterway, and shocks from bodies floating down stream would soon destroy the bridge.

The lightest woods obtainable, such as fir, pine, larch, willow, &c., should be chosen, avoiding such heavy wood as oak, teak, &c.

The size of the trees may vary from 25 to 45 feet in length, and from 30 to 70 inches in girth.

Rafts of timber are most conveniently put together in the water, on account of the ease with which the timber can be moved about: if formed on land, it should be, if possible, on ground sloping gently to the water, and the timbers should be laid on *ways* to facilitate launching.

In arranging trunks of trees, or other large timbers, for a raft pier, the shape shown in Fig. 450, Plate LI., should be given to the pier, if in a non-tidal river, so as to present a bow to the current. The timbers should be connected by braces, &c. A second tier of timbers (as in the left of Fig. 451) may frequently be requisite, in order to obtain the desired buoyancy.

551. Figs. 450, 451 show in plan and section a bridge of timber rafts thrown across the Danube, a non-tidal river, by the Russian Army in March, 1854.

Each pier was formed of seven logs contiguous to each other (the thicker ends directed up stream) and pointed as shown in the plan.

Two piers were formed into a raft, the interval being 6 or 7 feet.

The rafts formed in this manner were at like intervals, and were so connected by baulks as to allow of a motion adequate to the very slight movement which these long rafts could acquire from the small waves of the Danube.

Each pier had an anchor up stream, the cable being made fast to a small wooden capstan fixed on a platform near the ends of the logs. There was also one anchor down stream for each raft (two piers), the cable being fixed to a small capstan on a platform between the piers.

The roadway, which was 14 feet in width, was placed with its centre over the centre of flotation of the piers; and in addition there was a footway the whole length of the bridge, about 2½ feet wide, between the carriage way and the larger ends of the logs.

* To prevent this as much as possible, the ends of the timbers should be tarred, as stated in the General Rules, Art. 499, par. 7.

When the logs were small and insufficient, supplemental logs were placed in the intervals under them, as shown at *x*, Fig. 451.

552. *Flying or Swinging Bridges.*—A flying bridge is one in which the action of the current is made to move a boat, or raft of two piers, across a stream, by acting obliquely against its side. The side of the boat, or boats, should be kept at an angle of about 55° with the current.

In every case it is desirable to use long, narrow, deep boats with vertical sides (such as canal boats), to which lee boards may be attached, because the longer the boats that are used the greater length of side there is for the current to act upon, and also the bow offers less resistance to the current when it is narrow than when it is broad. The weight of the boat, or boats, should be considerable as compared with that of the cable.

Straight reaches are generally the most suitable parts of rivers, being most free from irregularities of current or backwaters. A velocity of two miles per hour at least is wanted in the current.

Landing stages should be formed at each bank.

Ramps which can be raised or lowered are convenient at each end of the raft.

There are three ways of working flying bridges—

(1) By using a suspension cable, as in Fig. 460, Plate LIII.

(2) By using anchorages and swinging cables, as in Fig. 458.

(3) By using a warp.

553. *Bridge with Suspension Cable* (Figs. 459, 460).—A post is set up on solid ground on each bank, and well stayed or strutted; the top has a cap with a grooved bearing for the cable to rest in. The cable is got over, raised, anchored, and strained as taut as its strength will allow. The centre of the curve should be well above the highest flood level. As the steepest parts of the curve are near the posts, these should be placed as far back from the banks as the strength and length of the cable will permit; the pulley to which the raft is attached, and which rests on the cable, has then only to travel on the central parts of the curve. Figs. 463, 464 give details of the pulley. Two lines are attached to this pulley and to the raft. The length of the longer one can be varied as required, and for returning it is shifted to the other side.

This method is employed in India, where spans of over 400 yards are crossed by using wire cables (which are always best).

554. *Bridge with Swinging Cable* (Fig. 458).—In bridges with a swinging cable, the length of the cable should be from $1\frac{1}{2}$ to 2 times the breadth of the river; and if the cable be long, it must be supported on intermediate buoys or floats, or better still, on masts placed in the bows of the boats, to prevent the cable dragging in the water. The boat nearest to the anchors should be moored as shown in the figure, and ought to be distant from them 10 times the depth of the stream. The cable end is secured near the middle of the flying bridge, and the boats are steered; or the cable may be fastened to the bight of a rope, as in Fig. 458, the two ends of which are taken in or let out, to give the required inclination to the current.

A bend of a river, as in Fig. 462, may sometimes afford a convenient anchorage on land.

In a very rapid current, the cable may be anchored to the opposite bank, thus obviating the necessity for the boat moving upstream in its passage across. In this case, a second cable anchored on the near bank of the river (Fig. 461) must be provided, and taken back for the return journey; and four landing places will be required. When each boat reaches the lower landing place, it will be hauled up to the upper one, whence it starts again.

If the river be too wide for a simple flying bridge, the passage may be effected by means of one cable to a boat or buoy moored in the centre, and by a second cable from the boat to the opposite bank. The end of the cable not in use should be left on the boat or buoy from which the second cable has been taken.

555. *Bridge with a Warp* (Fig. 462*a*).—The third method is to stretch a warp across the river and let it run on rollers, as at A, B, and C, in Fig. 462*a*. A and B are used in going one way as in the figure, and A and C on the return journey.

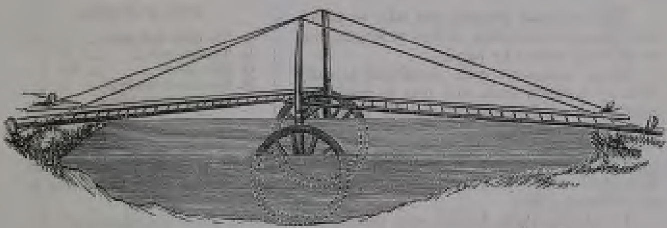
Flying bridges sometimes hang as they near the banks, on account of the current slackening; a line from the pier buoyed in their track may in such case be used to pull them in. A spare anchor and cable should also be kept on board, in case the swinging gear breaks.

Flying bridges used in the face of an enemy should have musket-proof parapets formed on their exposed sides.

556. Bridges for Crossing Small Streams, &c.—The bridges that have been hitherto described are those ordinarily used for the passage of large streams; in general they require considerable preparation beforehand, in order to construct them with ease and rapidity; but small streams, ditches, &c., may form serious impediments to the movement of troops, and afford ample scope for ingenuity in devising methods of passing them with the materials that happen to be immediately procurable. Some of the methods that have been successfully followed in various cases will now be described.

557. *Limber Ladder Bridge.*—This is shown complete in Fig. 469, and may be thus formed:—A cart is run into the stream with a ladder secured to it (the

Fig. 469.

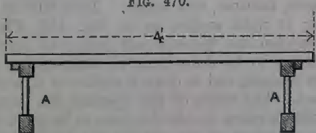


limber of a field gun, with the boxes removed, may be used); the shafts are then raised into a vertical position, and secured by guy ropes to pickets on either shore. A second ladder is then passed to the opposite shore. The ladders are secured to the splinter bar, or to a beam lashed across the shafts at a point which will suit the depth of the stream. The rungs of the ladders are then covered with planks.

This bridge is suitable for infantry in single rank. In broad streams two or more pairs of wheels may be used, so as to divide the whole length of the bridge into portions suited to the lengths of the ladders that are available.

558. *Trussed Ladder Bridge.*—A ladder laid on its edge forms a species of trussed beam, and may frequently be used as such in the absence of strong beams. The following is a description of a portable bridge (shown in section in Fig. 470) which was used in the operations in China in 1860, to enable the General and his cavalry escort to cross canals in reconnoitring the Peiho forts.* Two beams 24′

Fig. 470.



A A. Ladders acting as beams.

* The detail of the drill for making a trussed ladder bridge of this kind and also the limber ladder bridge is given at the end of the chapter.

long were formed out of four scaling ladders, each 12′ long, by lashing them in pairs, end to end, by means of planks 3′ long at the junctions. The beams so made were laid across the canals, and set up on edge in grooves cut in the banks for the purpose, the earth being banked up at their ends to keep them in position. Planks 4′ long were laid across, from beam to beam, to form the roadway; cleats were fastened under the outer edges of the planks to prevent their slipping off the beams.

This bridge, 24′ long, was laid and crossed in a quarter of an hour. Its total weight was 750 lbs., or about 31 lbs. per foot run. It was crossed by half a company of infantry, marching two deep, *in step*, with files well locked up, without suffering the slightest injury.

Bridges of this kind are made at the Royal Military College, where the beams, each formed of two 12-ft. scaling ladders, are greatly strengthened by being *trussed* in the following manner. A strong rope is passed on both sides from the upper side of the ladder at each end, underneath a block of wood placed beneath the centre of the ladder. If hauled sufficiently taut the rope will immediately take the strain, as soon as the ladders begin to bend from the weight pressing on them. To enable the rope to be hauled taut, the ladder resting (on edge) on the block of wood is bent downwards at each end while the tying is being effected.

559. *Portable Trussed Beams* (Figs. 465-6-7-8, Plate LIII.).—Beams of the kind shown here were used in the Ashantee Expedition in the construction of the bridge across the river Prah.

They are made portable and take to pieces, each piece not exceeding 10 feet in length, so as to be easily carried by hand.

These beams are each calculated to carry infantry in single rank, and may be used separately with a 2-feet pathway, or side by side to form a wide roadway.

Table of Weights.

A. Tie bolts and nuts ...	17 lbs.
B. Tension rods... ...	46 ,,
C. Side pieces	160 ,,
D. Shoes and brackets ...	70 ,,
Chesses in six pieces	103 ,,
Total	396 ,,

Two 2-feet roadways (Fig. 466), if used with a clear space of 2 feet between them, will carry 9-pr. guns (unhorsed), any available material being put down to act as wheel guides.

In placing these beams, care should be taken to keep the planes of the trussing vertical.

Frame Bridging. (Plate LIV.).

560. *Standards* in a frame bridge are the principal spars which support the entire structure. Their butts rest on the ground or other foundation for the bridge, in a manner similar to the legs of trestles.

Transoms are horizontal spars which connect the pairs of standards, and also carry the baulks of the roadway. They therefore require to be stout and strong.

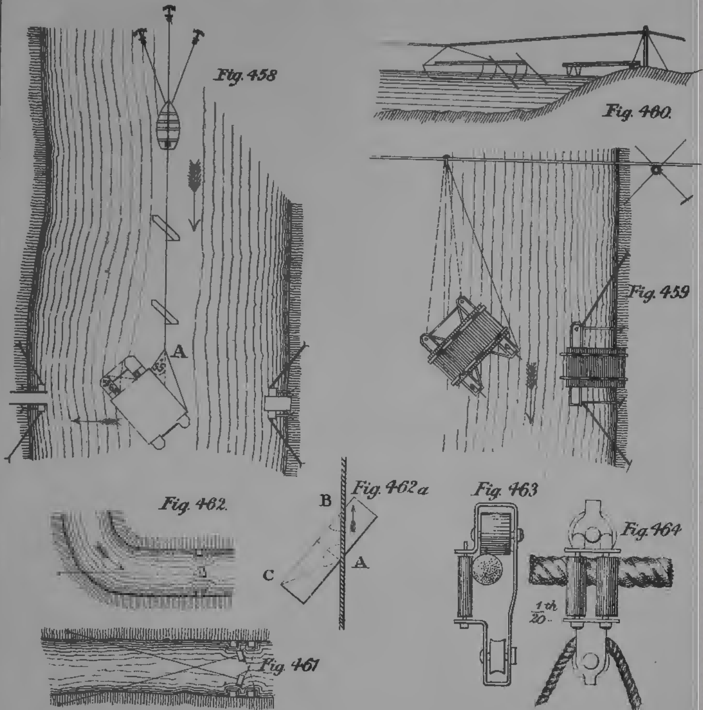
Ledgers are slight spars, used for the purpose of connecting together the pairs of standards, close to the butts of the latter.

Braces are slight spars which connect the pairs of standards diagonally; where they cross each other, they are also lashed. Their use is to stiffen the frame formed by the standards, transom, and ledger. They will be most efficient when they cross each other at right angles, as in Fig. 417, Plate XLVII. Their position is usually between the transom and ledger of each frame.

561. The first thing to be done prior to commencing a spar bridge is to measure the gap to be bridged, and to draw a section of it, with ropes and pickets, *full size*, on the ground. The width of the opening, the depth of the sides, and the length of the available spars, decide the form to be given to the bridge.

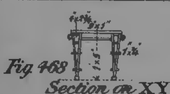
Whatever number of points of support for the baulks can be obtained, their distance from each other should be nearly the same; the total width of the chasm on the section is then divided into as many parts as there will be intervals

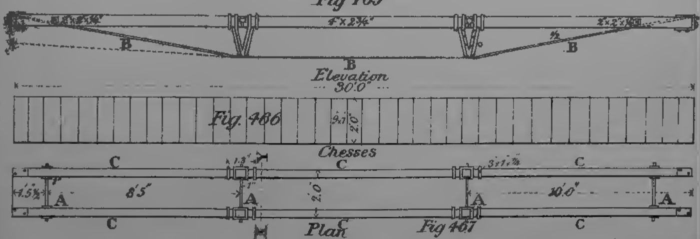
FLYING BRIDGES &c.



TRUSSED GIRDER.

Weight of Girder complete 396 lbs.





between the supports, and a picket driven in the line at each point to mark the position of a transom, the thickness of which is represented by a maul or piece of spar. The positions of the other spars can then be marked by lines or by the spars themselves, and the distance from their butts at which the transom will be lashed can be measured and marked on the spars to be used in making the bridge.

In lashing frames the butts of the spars should be further apart than the tips, to give greater stability. The splay may be about 1 in 20.

562. The Single Lock Bridge (Figs. 471–2–3, Plate LIV.), is suitable for spans of 30 feet or less. It is composed of two frames which lock into each other, as shown in Figs. 471 and 473: these frames should not slope more than $\frac{1}{4}$.

The bridge can be erected by a party of two or three non-commissioned officers and 20 men, one-half on each side of the stream or chasm: if the spars be heavy, the number of men may be increased up to 32.

The first operation is to take an accurate section of the gap, and to draw it full size (as in Art. 561) on the ground. On this section must be marked the positions suitable for the shore transoms or sleepers, or, where these are not required (as in Fig. 471, for a masonry bridge), the points such as E and F, where the road bearers will rest; also the position of the centre or fork transom, and the points A and B where the butts of the standards are to rest.

The standards A C and D B, Fig. 471, which represent one of each of the two frames, are then laid with their butts at the points A and B in the section (allowance being made as necessary for sinking, according to the nature of the footings), and the positions of the main frame transoms, C and D, can then be determined.

The object of making the section in the manner described is to obtain the distance of each frame transom from the butts of its own standards, *i.e.*, the distance of C from A for the frame to be formed on the left side of the gap, and that of D from B for the frame on the right shore. Marks are made on the standards at C and D, and are drawn at right angles to them from the *upper* edge of their respective transoms.

The standards for the two frames are got into position on each bank opposite the site for the bridge, their butts being placed towards the stream; the inside dimension of the wide frame being made a few inches greater than the outside dimension of the narrow frame at the position of the transom, so that one frame may fall inside the other when hauled across the stream.* The ledgers are lashed on above, and the transoms beneath, the standards at the positions marked; the diagonal braces are then lashed to the standards (two butts and one tip above them) and to each other. Two men work at each lashing, and great care must be taken that the spars are kept in their relative positions all the time, checking the measurements of the diagonals of the frames before the braces are lashed.

In the meantime the footings for the butts of the frames can be prepared, and pickets driven for the foot and guy ropes. The pickets for the former should be about 2 paces from the bank, and 4 paces on each side of the central line; those for the guy ropes about 20 paces from the bank, and 10 paces on each side of the central line. The foot ropes can also be secured by timber hitches to the butts of the standards, the fore and back guys to the tips, and the fore guys passed across to the opposite side by means of spunyarn, &c. The guys of the narrow frame should be inside the guys and the standards of the wide frame.

563. When all is ready, the frames are got into position, either one after the other, or both at the same time if there be sufficient men. One man is told off to each foot rope, and one to each back guy, to slack off as required, two turns being taken with each of these ropes round their respective pickets. The other numbers

* The inside dimension of the narrow frame depends upon the intended width of roadway. For planks 9 feet in length the standards of the narrow (inner) frame should be 9′ 6″ apart at the position of the transom, and 10′ 6″ apart at the ledger in the clear; for the other frame 1′ 6″ further apart throughout, so that one frame may lock into the other.

raise the frame and launch it forward, being assisted by the men manning the fore guys on the other side of the stream, until the frame is balanced on the edge of the bank; the butts must then be gradually lowered into the footings prepared for them by slacking off the foot ropes the head of the frame hauled over till beyond the perpendicular, and lowered nearly into its ultimate position by slacking off the back guys, the men on the fore guys assisting to guide it. It can be kept in this position by making fast the guys to their pickets, until the other frame has been treated in a similar manner. The two frames are then gradually lowered by means of the back guys, and guided by the fore guys, until the standards of the narrow one rest on the transom of the other between its standards; the wide frame is then lowered, until the two frames lock into each other, their standards each resting on the transom of the other.

The centre or fork transom is then passed from the shore and placed in the fork formed above the two frames.

The operations thus far described should not occupy more than forty-five minutes, provided proper stores are available, and in position on either side of the stream.

The roadway should be laid as described in Arts. 573–4–5, and should not require more than twenty minutes, so that the whole bridge should be completed in a little over an hour.

If the bridge has to be made over a broken arch, &c., where the footings for the frames are to be in masonry, as in Fig. 471, one hour or more in addition should be allowed for forming them.

564. The following is an estimate of materials and tools for a single lock bridge of 30 feet span:—

4 spars of 22′ to 24′ (7″ at tip) for standards of frames.
1 ,, of 15′ (10″ throughout) for fork transom.
2 ,, of 15′ (9″ throughout) for transoms of frames.
2 ,, of 15′ (7″ throughout) for ledgers.
4 ,, of 20′ (4″ at tip) for diagonal braces.
2 ,, of 12′ (immaterial) for shore transoms.
10 ,, of 22′ (6″ at tip) for baulks or road bearers.
4 ,, of 22′ (slight) for racking down baulks.
40 planks, 9 feet long, 1 foot wide, for roadway.
8 guys, 3-inch rope, 20 fathoms each, for fore and back guys.
4 foot ropes, 3-inch rope, 6 to 9 fathoms each.
4 lashings, 2-inch rope, 8 fathoms each, for main transoms.
4 lashings, 1½-inch rope, 5 fathoms each, for ledgers.
10 ,, 1½-inch rope, 5 fathoms each, for diagonal braces.
10 ,, 1-inch rope, 3 fathoms each, for road bearers.
16 rack sticks and lashings (8 feet of 2-inch rope).
1 ball of spunyarn.
8 park pickets, 5 feet long.
2 mauls.
4 pickaxes.
4 shovels, field service.
2 rods, measuring, 6 feet.
2 tapes, tracing.
2 tapes, measuring, 50 feet.
1 bundle of pickets.

And the following, in addition to the above, when footings have to be made in rock or masonry:

4 crowbars.
4 striking hammers.
4 brick chisels or jumpers.

565. The Double Lock Bridge is suitable for spans of 40 feet, and consists of two frames which lock into a connecting frame of two or more *distance pieces* with cross transoms, as shown in Fig. 474; the gap is thus divided into three spaces, and the span of the road bearers is about 14 feet. The bridge can be constructed by a party of two or three non-commissioned officers and from 24 to 48 men.

The section of the gap being taken and drawn on the ground, the positions of the shore transoms or sleepers are first marked; the distance between them is divided into three equal spaces by blocks (or maul heads) at A and B, which represent the sections of the road transoms; the points, C and D, where the butts of the frames are to rest being marked, the standards are laid in position over the road transoms (allowance being made for sinking, according to the nature of the bottom), the distance piece is laid underneath and touching the road transoms, the positions of which are marked on it, when the positions of the main transoms, E and F, can be determined. The following measurements are then carefully made:—C E and D F to obtain the positions of the main transoms on their respective frames; also the distances of E and F from their respective shore transoms as a guide to obtain the final positions of the frames when slacking off the back guys.

566. The side frames are then lashed on each bank in the same manner as the wide frame of the single lock bridge, and are launched and lowered down to a little above their final position, and held there by means of the back guys. Two road bearers are got out from each bank to the main transoms, and men go out to each of those transoms. The two distance pieces are then got into position (if necessary, by a pair of sheers, or by a block and tackle lashed to the head of a standard) inside the standards, and the road transoms are placed, and lashed to the distance pieces at the points marked. The side frames are now lowered till they jam, and the framework is complete and self-supporting.

The operations thus far described should not occupy more than about two and a-half hours, and the roadway could be laid and the bridge completed in three hours. Extra time will be required if the footings have to be cut in masonry or rock.

567. The following is an estimate of materials and tools for a double lock bridge of 40 feet span:—

4 spars of 20′ to 22′ (7″ at tip) for standards of frames.	50 planks, 9 feet long, 1 foot wide, for roadway.
2 „ of 25′ (7″ at tip) for distance pieces of connecting frame.	8 guys, 3-inch rope, 20 fathoms each, for fore and back-guys.
4 „ of 16′ (9″ throughout) for transoms.	4 foot ropes, 3-inch rope, 6 to 9 fathoms each.
2 „ of 16′ (7″ throughout for ledgers.	8 lashings, 2-inch rope, 8 fathoms each, for transoms.
4 „ of 20′ (4″ at tip) for diagonal braces.	4 „ 1½-inch rope, 5 fathoms each, for ledgers.
2 „ of 12′ (immaterial) for shore transoms.	10 „ 1½-inch rope, 5 fathoms each, for diagonal braces.
15 „ of 20′ (6″ at tip) for road bearers.	10 „ 1-inch rope, 3 fathoms each, for road bearers.
6 „ of 20′ (slight) for racking down baulks.	20 rack sticks and lashings (8 feet of 2-inch rope).

And, in addition to the above, spunyarn, park pickets, &c., &c., as detailed for the single lock bridge.

568. Single Sling Bridge (Fig. 475, Plate LIV.).—This bridge can be used for spans up to 50 feet: it consists of 2 frames locking into each other in the same manner as inthe single lock bridge, and it provides three points of support, viz., one on each frame (at A and C in Fig. 475), and a third (at B) suspended by slings from the heads of the frames.

The bridge requires a party of two or three non-commissioned officers and from 30 to 48 men.

The section of the gap being set out, the span is divided by pickets into four parts, equal if possible, and blocks (or maul heads) are laid above the line at the points A and C, and the standards laid in position under them: these are then marked for the ledgers and for the main and upper transoms. The upper transom must not be less than 9 feet above the level of the roadway, so as to afford proper head room. (See Art. 499, p. 3).

The two frames are then lashed: in the narrow one the standards must be 9 feet apart, in the clear, at the roadway, and 8 feet at the top transom; and in the other frame $1\frac{1}{2}$ feet farther apart throughout. A snatch block, with a fall rove through it, is lashed to the tip of each standard of the narrow frame.

The frames are then launched, narrow one first, and got into position as in the single lock bridge; or, if necessary, by means of a pair of sheers.

A couple of road bearers are now got out to the main transoms, two men climb to the top to assist in getting into position the fork transom F, which is raised by means of the blocks attached to the tips of the standards; one end is raised first, and slewed into its fork beyond its final position, and hauled back again when the other end has been got opposite its fork.

The suspended transom B is then, by means of the blocks, got into a position a little above that it will finally occupy, and is supported by ropes, arranged as slings, in the manner described in next Article.

The operation of getting the frames into position will require about 3 hours, and the roadway can be laid and bridge completed in about 4 hours. Extra time should be allowed if the footings for the standards have to be cut in masonry or brickwork.

569. *Spanish Windlass Sling.*—A 3″ rope (one of the guy ropes) is sent up to the top on each side, passed over the fork transom F, down underneath the suspended one B, up again round the top one, and so on until there are four parts, or more, supporting the lower one: the ends are then secured together. Care must be taken that the suspended transom bears equally on each bight of rope, and also that the ropes do not ride over one another.

When the road bearers are laid, the thick end of a handspike is inserted in the space between the ropes passing up and those passing downwards, and by turning the handle several times round them, with the thick end as a centre, the ropes may be twisted and tightened up to the desired extent, until the transom is raised sufficiently. The handle of the handspike must be secured to one of the standards, or to a road-bearer, by a lashing; and to prevent accidents, great care must be taken that it be not let go in the operation of twisting.

570. In order to give the standards more support at the points of loading, A and C, it is desirable to have long outer road bearers continuous from A to C, and to lash them at these points to the standards; or, still better, if spars of sufficient length can be obtained, the standards can be strutted at A and C by the spars A E and C D, shown by the dotted lines. The loads at A and C are thus supported by the resistance to crushing of A D and A E, and of C D and C E.

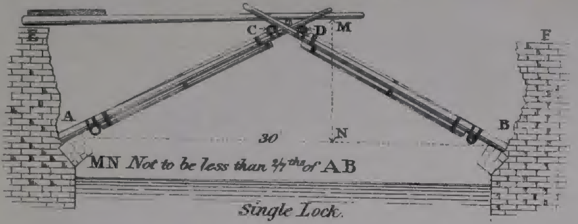
571. The following is an estimate of materials and tools for a single sling bridge of 50 feet span:—

4 spars, 35 feet (6″ at tip) for standard of frames.
3 ,, 15 feet (10″ throughout) for road transoms.
3 ,, 15 feet (6″ throughout) for top and fork transoms.
2 ,, 15 feet (4″ to 6″ throughout) for ledgers.
2 ,, 15 feet (4″ to 6″ throughout) for shore transoms.

60 planks, 9 or 10 feet × 12″ × $1\frac{3}{4}$″ for roadway.
8 guys, 3″ rope, 20 fathoms each, for fore and back guys.
4 foot-ropes, 3″ rope, 6 to 9 fathoms each.
8 lashings, $1\frac{1}{2}$″ rope, 8 fathoms each, for transoms.
4 ,, 1″ rope, 5 fathoms each for ledgers.

FRAME BRIDGES.

Fig 471.



Sketch shewing Frames and Centre or Fork, Transom in position.
Transom lashings indicated thus ✕
other lashings are not shewn.

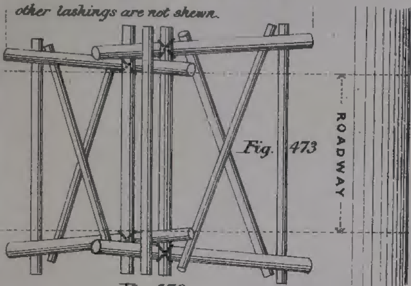


Fig. 473.

Sketch shewing Spars of one (outer) Frame, as lashed together on shore.

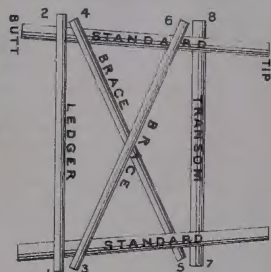


Fig. 472.

Fig. 474

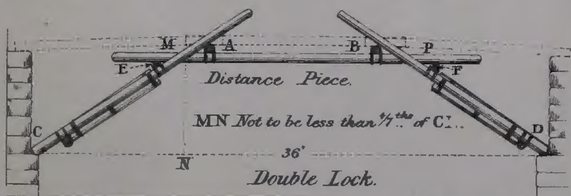
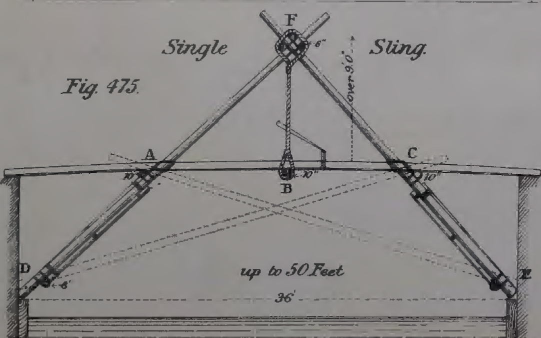


Fig. 475.



way has to be made of spars, the inequalities must be filled up with brushwood, clay, &c.

In removing the planks or chesses, the men advance as before by the right side of the bridge, lift the planks as they are turned up by the men on the road bearers, and leave the bridge by the left side, carrying the planks under the right arm. By following this method, the men do not get in each other's way, and there is a continuous supply of material brought on or removed from the bridge.

576. A ramp or slope of earth should be made at the ends of all bridges, where the roadway is above the level of the ground, to allow of the easy passage of carts, &c., on to the bridges: it should be covered with stones or planks if the traffic is likely to be heavy.

A handrail of rope on each side should be made by driving pickets at each end of the bridge, and making a clove hitch with the rope round the standards or other spars, about 3 feet above the level of the roadway.

ADDENDA TO CHAPTER XII.—CALCULATIONS (SIMPLE) FOR BUOYANCY AND STRENGTH OF ROAD BEARERS OF MILITARY BRIDGES.

577. A bridge of any kind ought to be more than strong enough to withstand the greatest possible stress to which it is liable to be subjected, and this rule must eminently apply to all military bridges.

Two distinct and separate conditions are required to be fulfilled in a floating bridge, viz. :—

(1) The floating bodies (piers), whether formed with pontoons, boats, casks, or rafts of timber, must have sufficient buoyancy to sustain with safety the greatest weight that can be brought to press on them.

(2) The baulks, or road bearers, which span the intervals between the saddles of the piers, must have the strength requisite to stand the greatest stress that can bear on them.

Art. 498 gives the weights brought on military bridges.

Every pier in a bridge has to sustain the weights which may press on the space between the points which are in the centre of the intervals between the piers; the distance between these points is equal to the sum of the halves of two adjacent bays of the bridge.

When the piers are arranged at equal intervals (as is usually the case) the distance is evidently equal to the central interval of the piers, or of one bay of the bridge. For this reason the maximum weight to be borne by each pier of a bridge will be composed of the maximum weight of passing bodies (troops, artillery, cattle, &c.) that can be packed on the length of one bay, in addition to the weight of the materials (superstructure) of the bay itself.

As remarked in Art. 499, nine-tenths of the buoyancy of closed bodies may be made available (an allowance of one-tenth being made for leakage), while with open boats or vessels their greatest immersion must not be so great as to risk their being swamped at the moment they are exposed to the greatest stress.

578. Buoyancy of Bodies.—The buoyancy in water of a *closed body* is found by subtracting the weight of the body itself from the weight of the mass of water it displaces (equal to its own bulk), when it (the body) is fully immersed.

When *open vessels* are used for the piers of floating bridges, the *available buoyancy* of each vessel will be found by subtracting its weight from that of the water displaced when it is immersed to its maximum intended depth.

When the central intervals between the piers of a floating bridge have been determined, the weight of the superstructure (road bearers, chesses, ribands, &c.) for one bay can be calculated; the *available buoyancy of one bay* of the bridge will then be found by subtracting the weight of the superstructure of the bay from the available buoyancy of the pier.

On the other hand, in cases when it may be required to determine the central intervals between the piers of a floating bridge, the dimensions and buoyancy of each pier being assumed to be known, it is necessary to estimate the probable weight of the superstructure of the bay; this weight of superstructure being deducted from the buoyancy of the pier, will give the available buoyancy of each bay of the bridge, which latter (in lbs.) being divided by the greatest weight (also in lbs.) that can press on each lineal foot of the roadway, will give, in feet, the maximum interval between the centres of the piers.

579. Strength of Baulks or Beams.—The strength of different beams of the same material varies directly with their breadth, inversely as their length (*i.e.*, clear distance between the points of support) and as the square of their depth. If, therefore, three beams of equal length have their breadth and depth as here stated, viz. :—

No. 1	...	1 broad × 1 deep.
„ 2	...	2 „ × 1 „
„ 3	...	1 „ × 2 „

their strength will be respectively as 1, 2, and 4; No. 3 beam having the same sectional area as, and therefore an equal weight with, No. 2, although it has double the strength. As a general rule, however, it is not advisable in military bridges to make the depth of baulks more than twice their breadth.

580. The baulks used as road bearers in a military bridge are liable to two different stresses: either the weight pressing on them is equally distributed over their length, as is the case when infantry or cavalry are moving across the bridge; or the weight may be more concentrated, as when artillery or laden wagons are crossing. In the latter case, as regards artillery, the greatest stress is caused by the gun itself; for when limbered up, about one-third only of the total weight is borne by the limber wheels, the remainder being borne by the gun wheels.

581. When beams are supported at each end, as is the case with the baulks of a bridge, they will support double the weight, if it be evenly distributed over their length, that they can do when the weight is applied to their centres. From this it will be apparent that artillery strain the baulks of a bridge in their passage over it much more than is the case with cavalry or infantry, even although the weight on each bay is less; but the difference will be even greater than might be assumed from the foregoing, for two reasons: (1) Because the weights allowed for are not in excess of the reality, as regards the passage of artillery, for the weight of a gun and carriage is fixed, whereas the weight of the infantry that presses on a bridge will in all probability be less than that estimated, on account of the men not keeping step, and therefore not closing up to one another. (2) Because the wheels of the gun carriage will not press evenly over the whole of the baulks, whereas with infantry the weight may be considered as equally distributed, not only over the length of the bridge, but also over the breadth of its roadway.

The following table gives the safe fraction of the *breaking weight* of various materials, called the *factor of safety*, which should be used for bridging purposes :—

Unselected wood, dry	...	$\frac{1}{3}$	Iron (wrought)	... ...	$\frac{1}{2}$
Selected „	... ...	$\frac{1}{2}$	„ (cast)	... ...	$\frac{1}{3}$
Rope, hemp, or wire	...	$\frac{1}{2}$			

When the weight is moving, the stress is considerably increased, particularly if the roadway be rough, which causes jolting. For the road bearers and transoms of a bridge (where the weight is applied gradually) it is considered that the live (moving) weight should be multiplied by $1\frac{1}{2}$ to obtain the equivalent dead (or stationary) weight; or in other words, the live weight is only two-thirds the dead weight; the stress in each case being the same.

582. The following is a good general rule for calculating the load which can be borne by timber of given length and scantling:—

If b = breadth in inches, d = depth in inches, L = length of span in feet.

STRENGTH OF RECTANGULAR BEAMS.

For fir, safe distributed dead load in cwts. $= \dfrac{b\,d^2}{L.}$

„ cedar and mahogany, about the same load as fir.

„ larch ... ... $\frac{3}{4}$ } that of load for fir.

„ beech, oak, and ash $1\frac{1}{4}$ } that of load for fir.

„ teak ... ... $1\frac{3}{4}$ } that of load for fir.

This formula gives a theoretical factor of safety of about 8; the practical factor of safety for large scantlings being about 5.

The strength of a circular pole is $\frac{6}{10}$ that of a square beam, the side of which is equal to the diameter of the pole.

When a beam is loaded with the safe load given above, the deflection in inches will be about $\frac{1}{30} \times \dfrac{L^2 \textit{ in feet}}{d \textit{ in inches}}$ for fir, oak, and mahogany; and one-half the same for teak.

If there are five baulks in a roadway, each baulk should be calculated to bear one-fourth of the total weight. This is done on the supposition that the two outside baulks only do half the work of the centre ones, which if not strictly accurate is an error on the safe side.

583. The following are the approximate weights per cubic foot of different kinds of timber:—

Ash	47 lbs.	Pine	40 lbs.
Beech	43 „	Poplar...	24 „
Elm	36 „	Sycamore	37 „
Fir	32 „	Teak (Indian)	41 „
Larch	32 „	„ (African)	61 „
Oak	54 „	Yew	50 „

584. The buoyancy of a cask is given by the formula—

$$5\,c^2\,l - W.$$

where c is the circumference of the cask in *feet* halfway between the bung and the extreme end; l is the length in *feet*, exclusive of projections, measured along a stave; and W is the weight of the cask in lbs.

585. The cubical content of unsquared timber may be calculated from the following rule:—

Multiply the square of one-fifth of the mean girth in feet by twice the length of the trunk in feet, to obtain the content in cubic feet.

Example: If the log measures 6 feet round the middle and is 20 feet long, the cubic content will be—

$$(\tfrac{6}{5})^2 \times 20 \times 2 = \tfrac{36}{25} \times 40 = 57\tfrac{3}{5} \text{ cubic feet.}$$

586. Examples of Calculations for Bridges.

Example I.—*It is required to find the greatest distance from centre to centre of the boats in a military bridge, under the following conditions:—The bridge to support infantry four deep, crowded by a check, which brings a weight of* 560 *lbs. on each lineal foot of the roadway. The floating bodies are flat-bottomed boats with upright sides,* 5 *feet wide and* 3 *feet deep: the greatest immersion of the boats to be* $2\frac{1}{2}$ *feet; mean length of the part immersed being* 16 *feet. The weight of each boat is* 1,000 *lbs.; that of the superstructure for the bay is* 120 *lbs. per foot lineal.*

Here $16'' \times 5'' \times 2\frac{1}{2}'' = 200$ cubic feet: the quantity of water displaced by each boat at the maximum intended immersion,
and $200 \times 62\frac{1}{2} = 12{,}500$ lbs.: the weight of water displaced by do. do.
Deduct 1,000 ,, for given weight of boat.
11,500 lbs. = available buoyancy of one bay, added to the weight of its superstructure.

If l = length of bay in feet.

$$l = \frac{11{,}500 - 120\,l}{560} = 17 \text{ feet nearly.}$$

Example 2.—*The boats acting as piers in a floating bridge are at central intervals of* 15′ 6″, *the span of the baulks is* 15 *feet, the width of the saddle beam being* 6 *inches. The baulks are five in number, but each is to be able to bear one-fourth of the total weight. The breadth of each baulk is to be one-half its depth. Calculate the breadth and depth of the baulks to carry infantry four deep, crowded by a check, as in last example.*

Here $560 \times 15 = 8{,}400$ lbs. live load, equally distributed, on the baulks.
$8{,}400 \times 1\frac{1}{2} = 12{,}600$,, dead load ditto ditto.
$\frac{12600}{4} = 3{,}150$,, 28 cwt. nearly, ditto on each baulk.

As, in this instance, the breadth of the baulk is to be one-half its depth, the formula $W = \frac{b\,d^2}{L}$ will become, $W = \frac{\frac{1}{2}d \times d^2}{L} = \frac{d^3}{2\,L}$

Substituting, we have $28 = \frac{d^3}{30}$; whence $d^3 = 840$, and $d = \sqrt[3]{840} = 9\frac{1}{2}''$ nearly.

As remarked in Art. 582, the above calculation gives a factor of safety of 8, which means that the maximum weight on each baulk will be only one-eighth of its breaking weight.

If a factor of safety of 5 (or $\frac{1}{5}$ breaking weight) be used, the calculation would result thus:

$$28 \times \tfrac{5}{8} = \frac{d^3}{30}; \text{ whence } d^3 = 525, \text{ and } d = \sqrt[3]{525} = 8'' \text{ nearly.}$$

Example 3.—*Required the available buoyancy, per lineal foot of roadway, of the bridge of casks shown in Figs.* 455, 456, *Plate LII., the weight of the superstructure being taken as* 120 *lbs. per lineal foot of roadway, and the buoyancy of each cask, as stated in Art.* 544, *being* 1,170 *lbs.*

The length of each bay, as stated in Art. 549, is 10 feet.
The number of casks to each bay or pier is 7.

The buoyancy of each cask is	1,170	lbs.
Deduct $\frac{1}{10}$ for leakage, &c. (General Rules)...	117	,,
Available buoyancy of each cask	1,053	,,
Ditto of the seven casks, $1{,}053 \times 7$ =	7,371	,,
Deduct weight of superstructure, 10 ft. at 120 lbs.	1,200	,,
Available buoyancy per bay	6,171	,,
∴ Buoyancy of bridge per lineal foot = $\frac{6171}{10}$ =	617	,,

This is ample to carry infantry in fours, crowded by a check; also 25-pr. M.I. Guns. See Table in Art. 498 for weights of guns, &c.

EXAMPLE 4.—*What should be the greatest central interval between the piers of casks in preceding example to carry infantry in fours, crowded by a check?*

The available buoyancy of the seven casks of each pier is stated in Example 3 to be 7,371 lbs.

Weight of infantry in fours, crowded, is	560	lbs.	per lineal	foot.
Ditto superstructure	120	,,	,,	,,
Total weight carried by each pier is ...	680	,,	,,	,,

Consequently $\frac{7371}{680} = 11$ feet (nearly) is the required maximum interval.

DRILLS FOR BRIDGE-MAKING ARRANGED TO SUIT THE WORKING SQUADS AT THE R.M. COLLEGE, SANDHURST.

587. SINGLE LOCK SPAR BRIDGE.

DETAIL OF DUTIES, ETC., WITH A WORKING PARTY OF 1 N.C.O AND 16 MEN.

Fall in, two deep, with stream (or gap) on the right.

Number from right of both ranks. Front rank work on left bank of stream: rear rank on right bank.

8	7	Front rank.
6	5	
4	3	
2	1	

Form parties.—Even numbers of each squad step to rear, the whole squad turn to right (towards stream), so as to have the even numbers on the right, odd numbers on the left of each squad.

1	2	Rear rank.
3	4	
5	6	
7	8	

Form frames.—Nos. 1, 2 bring up the ledger; 3, 5 on the left, 4, 6 on the right, bring up the standards; 7, 8, the transom. Transom must be first laid on the ground, then the standards, lastly the ledger. In lashing, 1, 3 and 2, 4 will lash the ledger to the standard; 5, 7 and 6, 8 will lash the transom. (See Fig. 472, Plate LIV.)

Braces will be brought up by 1, 2 and 7, 8, and lashed by same numbers as lashed ledger and transom; centre lashing by non-commissioned officer.

Make fast guy and foot ropes.—Nos. 1 and 2 attend to the foot-ropes; 3, 5, 7 and 4, 6, 8 to the guys, each on their own side. Park pickets to be driven as required by Nos. 7, 8.

Pass over guys.—In passing guys to opposite bank, those of narrow frame must be passed *inside the standards* of the other (broad frame).

Prepare to launch frames, lift, forward, steady, down.—When the frames are lowered, foot ropes to be secured.

Man guys, turn over.—Frames are hauled by means of the guy ropes, so as to turn over and lock one into the other, the narrow frame being inside.

Belay guys.—Guys are secured to park pickets or to available trees.

Fork or road transom.—Nos. 7, 8 right bank bring up the fork transom, and pass it on to the frames, assisted by 7, 8 of left bank, who get on to the frames and adjust it. They remain on the frames to assist in adjusting the baulks, after which they rejoin their squad on shore.

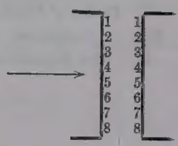
Baulks.—Nos. 1—6 bring up a baulk each, No. 7 a plank; Nos. 7, 8 adjust the baulks, using a plank as a guide in laying them. Nos. 7, 8 on each side then secure the baulks by pickets on each side.

The whole party then fall in, two deep, on the bank where the superstructure is stored.

Lay planks.—Nos. 1 stand on the baulks with their backs to the stream, and lay all the planks as they are brought up. The other numbers (in order, 2, 3, 4, &c.) bring up the planks, carrying them under the *right* arm. (If planks are carried by single men, the front rank of each file leads; if by two men each, they are carried by files, the front rank man being in advance.) The men advance by *right* of bridge, wheel to left at head of roadway, hand over planks to Nos. 1, and retire by the left, and bring up more planks as may be required.

Fall in, two deep, on side where ribands are stored.

Prepare to rack down.—Nos. 1 and 2, 3 and 4, 5 and 6 on each side will carry the ribands, and lay them in position on their own side of bridge. Nos. 7, 8 on each side will carry four rack lashings, and distribute them along their own side; Nos. 7 along the front (head) half of the bridge, Nos. 8 the rear ditto. The whole of the men then stand up on their own side, rack lashing in hand, facing outwards.



Rack down.—Each number will secure its lashing properly, with the stick on the outside of riband, and its head to the right; then sit down with feet over side of bridge.

Attention.—Stand up and face the head of the bridge.

Form handrail.—Face inwards and join hands.

588. Double Lock Spar Bridge.

DUTIES, ETC., OF WORKING PARTY OF 1 N.C.O. AND 16 MEN.

Detail of work, same as for the single lock bridge, until the frames on each bank have been hauled into position, and left suspended by the back guys.

N.B.—One distance piece and one top transom to be on each bank.

Distance Pieces.—Nos. 1, 3 (on left) and 2, 4 (on right) on each bank get on to the transom of their own frame, and assist to get the distance pieces (and afterwards the road transoms) into position. The distance pieces to be brought up by Nos. 5, 7 (by means of ropes secured at each end with a timber hitch and a half-hitch) on their own left side of bridge; when they have hauled over the distance pieces to Nos. 1, 3, they (Nos. 5, 7) bring up two baulks and lay them on to the transom of their own frame to form an incline, on which to roll forward the road transom.

Road Transoms.—Nos. 6, 8 bring them up (secured by timber hitches), roll them on the inclined baulks, when Nos. 1, 3 and 2, 4 adjust them *above* the distance pieces, and *under* the standards, and touching both.

Lash.—Nos. 1, 3 and 2, 4 of each bank lash road transom to distance piece. While lashing is being done, Nos. 5, 6, 7, and 8 bring up the baulks in readiness to be laid, also a plank to guide the men in laying them.

Baulks.—The baulks are then passed from each shore to Nos. 1, 3 and 2, 4, who adjust them on the road transoms; Nos. 5 and 6 attend to them on shore. When adjusted, Nos. 7, 8 picket the baulks.

The baulks of the shore bays to be close to the outside edge of the planks, in order that those of the centre bay, which are to be laid inside them, may be properly secured by the rack lashing.

The working party then fall in, two deep, on the bank where the superstructure is stored.

The remainder of the work is the same as detailed for single lock bridge, the successive words of command being—*Lay planks; Prepare to rack down; Rack down* and (if necessary) *form handrail.*

589. "BOOMING OUT" A TRESTLE BRIDGE WITH FOUR-LEGGED TRESTLES, AS IN FIGS. 418, 419, PLATE XLVII.

DETAILS OF DUTIES, ETC., WITH A WORKING PARTY OF 1 N.C.O. AND 16 MEN.

Fall in, two deep, with stream on right.

Number from right of each rank.

Right turn. Open out to width of roadway.—Front rank work on left side of bridge, rear rank on right side.

Duties of Numbers while forming each successive Bay of the Bridge.

Nos.	Designation.	Duties.
1.	Foot Rope Men.	Place bight at middle of foot rope over the off leg of trestle before it is turned over on to the *ways;* pay out while trestle is being lowered; when trestle is adjusted, withdraw foot rope, laying it in centre of the bridge, and about 6 feet from the head of the finished portion of roadway. They then stand on the outer baulks, back to the stream, and lay the chesses (planks).
2.	Boat Hook Men.	With boat hooks gently push trestle down the *ways;* when down, assist to turn it over on to its legs (taking especial care not to *overturn* it). They then measure the length of bay by means of the marks on the boat hooks. When trestle is adjusted, lay boat hooks in centre of bridge and close to foot ropes. They then assist to lay the baulks of the new bay.
3.	Way Men.	Each brings up one of the *ways,* and places it in position for the trestle to be lowered upon it, making fast the lashing to some convenient portion of the bridge. When the trestle is adjusted, withdraw *ways* (lashing still on), lay them in the centre of bridge, and close to boat hooks. Both numbers then get on to head beam of trestle just laid, and assist to lay and adjust the baulks of the bay.
4, 5, and 6.	Trestle and Chess Men.	Bring up each trestle, end on and head downwards, by the right of the bridge; wheel to the left at head, and lower trestle on to roadway. When foot ropes are on, they turn the trestle over on to the ways, man the foot ropes on their own side, and assist (if necessary) to haul the trestle into position. Then bring up three chesses in succession, by right of bridge, hand them to Nos. 1, and retire by the left side.
7 and 8.	Baulk and Chess Men.	Bring up two baulks to act as *levers,* and assist to *turn over* each trestle. When trestle is adjusted, hand these baulks to Nos. 2, who lay them as outside baulks, and then bring up the remaining baulks of the bay, 3 (or 4) in number.* Bring up two chesses in succession to Nos. 4, 5, 6, and hand them to Nos. 1.

* If 18 or more men be available for the works, Nos. 9 should bring up and apply the *lever baulks* for each bay.

Prepare to boom out.—Nos. 1 get ready the foot ropes, Nos. 2 the boat hooks, Nos. 3 the ways, Nos. 4, 5, 6 turn the first trestle to be used on to its head, and prepare to carry it, Nos. 7 each take hold of a (lever) baulk.

Ways.—Nos. 3 launch the ways, so that their feet hold in the bottom of stream at the proper inclination; they then secure the lashings to bridge.

Trestle.—The trestle is then brought up as described.

Halt: Down.—Trestle is lowered gently on to bridge.

Foot ropes.—Nos. 1 then adjust foot ropes on to off leg of trestle.

Turn over.—Nos. 4, 5, 6 then turn the trestle over (assisted by Nos. 1 with the foot ropes) on to the ways, and lift the head of the trestle clear of the bridge baulks already laid. They then man the foot ropes.

Lower.—The trestle is *gently* and *slowly* pushed down the ways by the boat hook men (Nos. 2), the foot rope men checking the descent by means of the foot ropes.

Lever baulks.—Nos. 7 then adjust these baulks under head of trestle; Nos. 8 double man the levers to assist.

Turn over.—Nos. 2 with boat hooks, Nos. 7 and 8 with the lever baulks, then lift up the head of the trestle, and push it into the upright position. Nos. 2 then measure the breadth of bay with their boat hooks.

Adjust distance.—If necessary, by hauling on *either* or *both* foot ropes.

Baulks.—The baulks are then brought up by Nos. 7, 8, laid by Nos. 2, 3, as detailed.

The foot ropes, boat hooks, and ways are withdrawn, and laid, as detailed, in readiness for use with next trestle.

Chesses.—Nos. 4, 5, 6, 7, and 8 in succession bring up the chesses in manner detailed, and hand them to Nos. 1. Nos. 1 get on the outer baulks and lay the chesses.

When the last chess of each bay is laid, the operation is repeated.—*Ways, Trestle,* &c., &c., until the roadway is laid across the stream.

The "racking down" is then effected in the manner described for a single lock spar bridge.

590. Piers of Casks.

DETAILS OF DUTIES, ETC., FOR CONSTRUCTION OF PIERS OF SEVEN CASKS WITH A WORKING PARTY OF 2 DETACHMENTS, EACH CONSISTING OF 1 COMMANDER AND 7 MEN.

Fall in, in single rank, with stream on left, ranks closed up, and commanders on the left: each detachment is sized from right to left.

Number from right of each detachment.—Commanders and Nos. 1 are *gunnel men,* the remainder are *brace men.*

Prepare to form pier.—The four gunnel men bring up two gunnels, and lay them outside the position of the pier, *i.e.,* perpendicular to the bank, and parallel to the pier; Nos. 2, 3, 4, and 5 front detachment, and 2, 3, 4 rear detachment, each bring up one cask and place them in line between the gunnels with their bungs uppermost. No. 5 rear detachment brings 2 breast lines and 1 boat hook, lays one breast line on ground at each end of pier, boat hook at shore end of pier and on the ground. Nos. 6 bring up 6 braces each, and distribute them on their own sides of the casks outside the gunnels. Nos. 7 each bring up a sling, and place them loop end towards the stream and under the ends of the casks, and on their own sides of them. The party then fall in, facing inwards, on their own sides of the pier.

Line casks.—The odd numbers of each detachment (except No. 1 rear) place forefinger of right hand on bung of cask to their own right. The even numbers move the casks as required.

Steady.—Odd numbers remove fingers, and all stand at attention.

Gunnels.—The brace men stoop down, the gunnel men lift the gunnels (over heads of brace men) and place them on the casks about 4 inches from their ends, with centre mark over middle of pier; the brace men stand up and place both hands on gunnels, to keep them in place.

Slings.—Commanders pass loop of sling over end of gunnel, keeping it upright; Nos. 1 then take up the other end, and facing the commanders, place inward feet on cask and haul taut; take one turn round the gunnel from the inside, and belay with two half-hitches. Brace men keep slings in position with their feet if necessary. When slings are fixed, gunnel men stand at the end of gunnels and hold them steady with both hands.

Braces.—Each brace man provides himself with a brace, he passes eye of brace under the sling in the centre of interval between casks, draws end through eye, and hauls his brace taut down to the eye (keeping sling steady with his feet), then coils up brace, holds it in right hand, and removes foot from sling.

Take a turn.—Each brace man takes a turn round the gunnel to the *left*, exactly over the eye of the brace, and throws coil behind him to his *right* rear.

Heave and hold on.—Each brace man hauls up standing part of brace with left hand, and holds on with his right by the turn; then places left hand on turn, and coils up remainder of brace with right hand.

Cross.—Each brace man places his own coil on the cask to his left, using right hand only.

Two.—Takes coil of opposite brace man from the cask on his right, under the gunnel *to left* of standing part of his own brace and below the knot thereon.

Three.—Passes brace round standing part of his own brace *to the right*, and places it (under the gunnel) on the cask to his right from which he first took it.

Four.—Then takes his original brace from cask on his left, passes it under the gunnel to the left of standing part, and holds on to it. (Fig. 453.)

Prepare to rock and heave.—Brace men step back a short step, place left foot on gunnel, and haul taut the braces.

Rock and heave.—The rear detachment commence by hauling, front detachment push with their feet, holding their braces taut, the gunnel men assisting to move the pier; the front detachment then haul, rear detachment push, and the pier is rocked backwards and forwards three or four times, the braces *being hauled taut all the time.*

Steady.—Brace men remove feet from gunnel, keeping the braces taut.

Take a round turn.—Each man takes a turn round the gunnel with his brace to the left, and holds it down with the heel of his left hand.

Make fast.—Makes fast end of brace with two half-hitches round the two parts of his own brace near the gunnel, hauls them taut, and places spare end (if any) of brace between the casks.

The whole then stand at attention.

Prepare to turn pier to the right.—Front detachment place both hands on the gunnel, rear detachment stoop down and take hold of the casks.

Turn the pier.—Rear detachment lift, front detachment haul on the gunnels till the casks stand on end.

Fix breast lines.—The commander and No. 1 front detachment each fixes a breast line, with a clove hitch round the upper and lower slings respectively, close under the gunnel at his own end.

Adjust slings.—Brace men see that the upper sling is straight and just below third hoop of casks.

Prepare to lower the pier.—Front detachment stoop down and take hold of the lower gunnel, rear detachment take hold of the tops of the casks.

Lower the pier.—Pier lowered gently. All stand at attention.

Prepare to turn pier to the left.—Front detachment stoop down and take hold of the casks, rear detachment take hold of gunnel.

Turn the pier.—As before.

Adjust slings.—As before.

Ways.—Gunnel men bring up the ways, placing them close behind the front detachment, who must stand close to the casks. They (gunnel men) must see that the way ropes are clear.

Prepare to lower the pier.—Rear detachment stoop down and take hold of gunnel, front detachment take hold of tops of casks.

Lower the pier.—Rear detachment lift, front detachment haul and lower the pier gently on to the ways. All stand at attention. The commander and No. 1 of the front detachment place the coils of the breast lines on the end casks, and No. 5 rear detachment places boat hook on the shore end of the pier.

Man the way ropes.—Nos. 6 and 7 man front way ropes; commanders and Nos. 1 take hold of pier to push it forward; Nos. 4 and 5 man centre way ropes; Nos. 2 and 3 man rear way ropes.

Launch the pier.—All move forward; each number as he gets to the edge of the water falls to the rear and assists to push the pier. Commanders take hold of the breast lines on their own side, No. 1 front detachment takes the boat hook and pushes the pier, as soon as it floats, off the ways, which are pulled on shore by Nos. 2 assisted by the other men as soon as the way ropes come out of the water.

Ways to the rear.—Ways are then retired and laid ready for further use with all the ropes clear.

When the men are expert at working in slow time the piers may be formed by the following words of command only:—

Forming Piers of Casks in Quick Time.

Prepare to form pier.
Line casks. Steady.
Gunnels.
Slings. } As before.

Braces.—As before, but braces to be kept coiled in right hand.

Heave and hold on.—As before; braces do not require coiling.

Cross.—Crossing to be completed without further command.

Rock and heave.—Pier to be got in motion at once.

Round turn and make fast.—As before.

Turn pier to right and fix breast lines.—As before; sling to be adjusted by rear detachment.

Lower the pier.—As before.

Turn pier to left and bring up ways.—Ways to be brought up and sling adjusted at once.

Lower the pier.—As before; way ropes to be manned at once.

Launch the pier.—Pier to be launched as before; ways to be withdrawn without further command.

591. Limber Ladder Bridge with Working Party of 8 Men.

STREAM.

1	2
3	4
5	6
7	8

Party falls in, single rank, right resting on stream. *Number.*—Odd numbers 4 paces to the front, march. The whole to the right turn.

Before commencing to form bridge the limber boxes should be removed, and the shafts reversed.

Form bridge.—Nos. 1 and 3, 2 and 4, place one ladder between the shaft of the limber, tip to the front, and resting on the splinter bar over the iron strap, the outer side of the second round of the ladder being about 2½′ from the strap.

Lash.—Nos. 1 and 2 on their own sides (with the lashing on the ladder) lash the tip of the ladder *loosely* to the iron strap on splinter bar. Nos. 3 and 4 lash hand spike or a short length of spar across the shafts, about 1 foot from the end, and over the ladder; lay a second handspike or short spar on body of limber. Nos. 5 and 6 make fast to top of shafts the back and fore guys, coil up and place on the limber the fore guys in readiness to pass to opposite bank, lay out the back guys to the rear inreadiness to be manned. Nos. 7 and 8 on their own sides place on the limber two foot ropes each, and prepare stores for the second half of bridge.

Prepare to boom out.—Nos. 1 and 2 man back guys and pay out as required.

Lift.—Remaining numbers on their own sides lift the ladder.

Forward.—By means of ladder, push the limber into stream. When in position, *steady, down, adjust ladder* (if required).

Prepare to boom out second portion.—Nos. 1 and 2 on limber, facing inwards, hold handspike across at each end; Nos. 3 and 5, 4 and 6 bring up second ladder, tip to the front, passing it over the ladder already in position, and over handspike held by Nos. 1 and 2, bearing down on the butt, at the same time pushing it forward till it reaches the opposite bank.

Steady, down.

Cross over.—Nos. 3 and 4 cross to opposite bank, and drive in two strong pickets, to which to make fast the guys.

Adjust ladder.—Nos. 1 and 2 on the limber, 3 and 4 on the shore, adjust ladder in position, butt of second ladder over tip of first.

Foot ropes and guys.—Nos. 1 and 2 pass over fore guys to opposite bank, make fast foot ropes to one of the spokes of the wheel below and on each side of the axle tree, and pass them to Nos. 3, 5, 4, and 6.

Man guys.—Nos. 3, 5, 4 and 6 man back and fore guys; 7 and 8 drive in two stakes on near bank for guy and foot ropes.

Together, heave (Nos. 1 and 2 assist to lift shafts up when guys are hauled on), *steady, belay guys and foot ropes.*

Planks.—Nos. 5, 6, 7 and 8 each bring up one plank, and lay it on rounds of ladder, commencing from the shore.

Clear bridge.—Nos. 1 and 2 remove the handspike which is lashed across the shafts (if required for head room), and proceed with it to the opposite shore for duty with Nos. 3 and 4.

592. Trussed Ladder Bridge with Working Party of 8 Men.

STREAM.

1	2
3	4
5	6
7	8

Party falls in, single rank, right resting on stream. *Number.*—Odd numbers 4 paces to the front, march. The whole to the right turn.

Prepare to truss ladders.—Each rank will truss one scaling ladder, Nos. 1 and 7, 2 and 8 bring up each a ladder on their own side, standing it on its edge; Nos. 3 and 4 each a wooden block about 1′ 6″ × 9″ diameter and place it under the middle of their own ladder; Nos. 5 and 6 each a 2½″ rope about 20 yards long, and lay them, doubled, close to and parallel to their own ladders, the bight or doubled portion of the rope towards the tip of the ladder.

Truss Ladders.—Nos. 1 and 7, 2 and 8 place themselves at their own ends of their respective ladders, and bear down on them, so as to form a *camber*.

Nos. 3 and 4 place the bight of the rope over their ladder and in front of the iron strap at the tip. Nos. 3 and 5, 4 and 6 pass the ends of the rope on each side of the ladder under the wooden block, through the iron strap at top of the butt end of the ladder, haul taut, cross over top rail, down, cross under bottom rail, up, round turn with each portion of rope, and make fast round standing part of cable with two half-hitches.

Prepare to pass over Spar.—Nos. 1 and 2 at centre of intended place of bridge, facing inwards, hold a handspike or short beam, &c., at each end.

Prepare to lift Spar: Lift: Forward.—Nos. 3 and 8 lift up spar, pass the tip over the handspike, &c., held by Nos. 1 and 2, and push forward until it reaches the opposite bank, at the same time bearing down on the butt to facilitate the operation.

Launch Ladders.—Nos. 1, 3, 5, and 7 bring up their trussed ladder, tip to the front, lay it on its side upon the spar across the stream, and push it gently till it reaches the opposite bank, when they will give it a gentle cant off the spar towards their left, letting the ladder lie flat. Nos. 2, 4, 6, and 8 will then pass their ladder over in the same manner, except that they will cant the ladder off to their right.

Withdraw Spar.—No. 1 (if necessary) makes fast a lashing to butt of spar, and all numbers withdraw spar to the rear.

Cross over.—Nos. 1 and 3, 2 and 4, by means of the ladders on flat, pass to the opposite bank.

Secure Ladders.—The numbers at each end cut small grooves in the bank, about 4 feet apart, to receive the ends of their own ladders on edge, and picket them down on each side with two or more strong pickets, making good the earth round the ends.

Planks.—No. 5, standing on the ladders, receives the planks from the other numbers on his own side of the stream (6, 7, and 8), and lays them.

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