Permanent Fortification For English Engineers

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LEWIS

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PERMANENT FORTIFICATION FOR ENGLISH ENGINEERS.

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INTRODUCTION.

THIS book is written to save Engineer Officers trouble.

This, it is hoped, it may do in two ways; directly, by forming a book of reference for details to those stationed where works are in course of construction; and indirectly, by giving assistance in the preparation of the projects which have to be considered by those at the War Office, who would be much helped by their being drawn up in agreement with the principles and practice recognized there.

The necessity for a work of this nature was impressed on me years ago when first employed on the designs of forts. There was no information to be got from books of many details which must have been used over and over again, and consequently much time had to be spent in devising them afresh. With the multiplicity of occupations in the Corps of Royal Engineers it must constantly happen that an officer passes years without having anything to do with Permanent Fortification, and therefore without being able to keep up his information at first-hand; and yet considering the number of our coast fortresses, of which there are over 40 already armed with heavy guns and more in prospect, it would be strange if anyone were to go through his service without being employed on one of them. Or again, an officer employed at one place on defences of a certain class might be moved to another where he would have to carry out works of quite a different character. In such cases the means of acquiring the necessary information would be found here.

The endeavour has been made that this book should be a practical one, and to this end several things had to be kept in mind.

The first was always to put down, as far as possible, how things actually are done, and not how they might conceivably be done better. Criticism is often tempting, and would probably, whether right or wrong, make the book lighter reading, but it is not of much help to a man who has to build a battery, and who wants to know such things as how thick an arch must be made to be shell-proof, or how to set his racers. For this reason references are often made to War Office circulars.

The second was not to give long descriptions of such things as modes of mounting guns which are not generally used, or which involve much machinery, as, for instance, Dover turret or the 100-ton gun emplacements. The general principles on which such batteries are laid out and adapted to the ground are those common to all. Their details must be worked out in connection with the designer of the machinery, and no one can have to erect them in a hurry and without opportunities of getting information.

The third thing was always to keep in view the nature of the attack to which English works are liable. This I believe can never be a regular siege in form, such as has to be contemplated, for instance, at

Metz or Verdun. The fleet is the dominating factor in English defence. This is spread over the whole world, and the defeat of a portion of it will not render it possible to neglect the rest. The certainty of its interference within a short time, renders it indispensable for an army which may have attempted an invasion of this country to strike a rapid blow. This is incompatible with the slow operations of a regular siege. Our outlying fortresses are similarly sheltered by the power of the fleet. Malta and Gibraltar might be considered exceptions, but there are local peculiarities about them which render it unnecessary to make great preparations against a land attack. Of our three land frontiers, the Cape is practically not in contact with a civilized power. The Canadian frontier is not fortified, as no army exists on the other side to attack it. If a large organised force were to be maintained in the United States, it would undoubtedly be necessary to fortify it on the Continental scale. On the N.W. Frontier of India our only possible antagonist would have too long a line of communication to bring up siege material, in addition to men and stores. It will be long before it is necessary to make the works on this frontier stronger than those in the rest of the Empire. The land works, therefore, which are here described, are considered to be suited to English use. We have not followed the Continental engineers into the lavish employment of iron and concrete, but have kept as yet to earthworks and mobile guns, which appear to me at present to be sufficient for our requirements; and in the coast works, too, very heavy armaments are not contemplated.

Finally, it must be pointed out that although events do move quickly in fortification, yet that this book will not necessarily become at once, or even for a long time, entirely obsolete. Many of the details described are of old standing. Many pages are transferred from the Lectures on Permanent Fortification, published in the Corps Papers in 1882, requiring but slight alterations, if any at all. And for years to come it will contain much information which will be novel to many officers, and will at any rate enable them to start fresh enquiries from a later date than would have otherwise been the case.

SEPARATION OF SUBJECT MATTER.

In arranging the subject matter of this book it has been thought advisable to separate the consideration of Land and of Coast Defences; for besides the difference in the character of the buildings which necessarily follows from the difference of situation and of ordnance used, there is an essential distinction in the principles of their use and construction.

The permanent land works are only a portion of the general scheme of defence of a place; they are one of the means prepared to assist the troops in holding a position; and they are usually intended to resist a variety of means of attack, directed with great care on the exact point which the enemy may think is the most advantageous for gaining his ends.

Coast defences are carefully prepared positions in which to mount the guns, with which, together with submarine mines and locomotive torpedoes, the naval attack must be resisted. These guns and torpedoes are the only means by which the attack of ships can be met from the shore, and everything must be arranged to permit of their most efficient action.

With land forts, on the contrary, the defence may be complete without any guns actually mounted on them firing a single shot, for in a siege it is desirable that the forts should remain quite silent, the artillery fire being delivered from detached batteries.

Against coast defences a careful direction of the enemy's fire to produce a breach is hardly possible, although the blows of individual projectiles may be terrific, much worse than anything that will be met with in a land attack. Moreover a coast work cannot be attacked by formal approaches; capture by surprise, escalade, or storm, are possible, but it cannot be sapped up to.

For these reasons the land and coast works are treated independently, and a beginning is made with the land works as the older branch of the art.

1.—LAND FORTIFICATION.

PRELIMINARY REMARKS.

Basis of Fortification.—"Permanent Fortification stands on the same basis as tactics—arms and contour of ground."

This sentence, from Colonel Hume's *Précis of Tactics*, clearly indicates how we should study the general principles of Fortification; that is, as a branch of Tactics; and one which, like the Tactics of an army in the field, requires change with each change in the power of the weapons in use, and with each new application made of them.

Definition of Fortification.—In fact, Fortification is the careful preparation of ground in such a manner that the defenders may use their weapons with the greatest possible effect, and with the least interruption from the enemy. All the changes made in fortification have been the consequences of the improvements that have been made in weapons.

It is the greatest importance always to bear in mind these principles. Most of the errors of Engineers arise from their exaggerating the constructional part of fortification, while those of officers of other arms come from their looking on it as an art somehow distinct from the tactics to which they are accustomed. Fortification is a branch of tactics.

Early Fortification.—In the earlier days of fire-arms, when their range was much less than it is now, the ground was prepared in a careful manner for the use of the weapons over a large part of the terrain of the attack, by bastions and ravelins, horn-works and lunettes, glacis and covered way.

The effective range of the S.B. musket limited the length of the line of defence in the old bastioned systems.

Effect of the Introduction of Rifled Weapons.—When rifled arms were introduced the terrain of the attack immediately developed enormously; the old system of outworks covered but a minute part of it. It was at once felt that the advantages of extending the works to the front were gone; it mattered little being 100 yards or so nearer the enemy, when he could ruin all the works at 1,500 yards off. The part played by the old outworks was no longer a leading one, and they were, therefore, diminished or omitted, and new arrangements were introduced to meet the altered condition of affairs.

A further development of the power of weapons has recently taken place in the same direction, and similar results must follow. The necessity for delaying the enemy by means of a material obstacle, in order to keep him under fire, no longer exists to such an extent as formerly, since the accuracy and rate of fire have so much increased. Consequently ditches and escarps are now of lessened importance.

We see, therefore, that before deciding on the proper mode of constructing fortifications, it is necessary to have some knowledge of the weapons and modes of attack in use, and of their possible developments.

2.—SIEGE ARTILLERY.

Siege Artillery.—Siege trains consist usually of guns of about 6 inches calibre and under, of rifled howitzers of about 8¼ inches calibre and under, and, in foreign armies, of rifled mortars of the same calibres as the howitzers. The use of larger guns and mortars has been advocated, and they would, no doubt, be used under some circumstances, but their employment would be limited to cases of real necessity, owing to the difficulty of moving them, and, more especially, of keeping them supplied with ammunition. The first obstacle to their use might be got over by carrying them in pieces, to be screwed together when wanted; but the latter is the most serious drawback.

The guns are used for direct fire against opposing artillery, against exposed masonry and iron protection, and with shrapnel against troops.

The howitzers are used with indirect or curved fire, *i.e.*, fire with reduced charges up to 15 degrees elevation, against earthworks and concealed masonry, and with shrapnel against troops behind parapets. When there are no mortars they would also have to be used against casemate roofs.

The rifled mortars would be used with high angle fire, *i.e.*, fire at angles over 15 degrees elevation, against casemate roofs and magazines; and, the smaller weapons more especially, with shrapnel against troops behind parapets.

All these weapons can fire shells charged with high explosives—either wet guncotton, pyrolixine, or melenite. The mortars in particular use what the French call obus-torpilles, *i.e.*, shell of about six calibres in length charged with a high explosive. The use of some high explosive in shells must in future be assumed as a matter of course.

Projectiles can act in two ways—either by penetration or by burst; and in the latter case they can be combined either with rapid or with delay-action fuzes.

Penetration would be used against vertical iron armour. The burst would be used against sloping parapets, but with a rapid fuze, since with a slow fuze the shell would ricochet before exploding,

and not being in contact a great part of the effect would be lost. Against steep parapets of the old pattern, delay-action fuzes would be most effective, as the shells would enter without glancing. Against casemate roofs covered with earth delay-action fuzes would be used, but if the concrete roofs be exposed rapid fuzes must be employed in order to burst in contact. In this case the shells must be strong enough not to break up on striking.

It is said that the effect of high explosives is very great against the cupolas for medium guns which are being used on the Continent, bending in and breaking the plates.

Accuracy.—In order to give some idea of the power and accuracy of the ordnance likely to be most commonly used in a siege, tables are given below of the ballistic effects of the 5-inch B.L., of the 8-inch M.L. howitzer with three different charges, of the 64-pounder M.L., and of the 15 cm. and 21 cm. rifled mortars. The latter are extracted from General Brialmont's book, *Influence du Tir Plongéant sur la Fortification, 1888.* The 5-inch compares fairly with the 12 cm. gun, the 8-inch with the 21 cm. howitzer (though the latter is of a somewhat larger calibre), and the 64 pounder resembles the short 15 cm. gun in ballistics.

5-inch B.L., Charge 16*lbs.*, *Projectile* 50*lbs.*, *Muzzle Velocity* 1,746 *f.s.*

Range, yards.	Elevation.	Angle of descent.	50 p.c. of rounds should fall within. Yards.			Remaining Velocity, f.s.
			Length.	Breadth.	Height.	
1,000	0° 51′	1° 9′	22·0	·42	·44	1,441
1,500	1° 28′	1° 58′	22·7	·65	·79	1,294
2,000	2° 11′	3° 2′	23·3	·90	1·24	1,173
2,500	2° 58′	4° 14′	24·6	1·17	1·86	1,073
3,000	3° 48′	5° 34′	28·2	1·47	2·72	1,007
3,500	4° 45′	7° 2′	32·0	1·81	3·86	954
4,000	5° 48′	8° 47′	36·0	2·20	5·56	905
4,500	6° 58′	10° 38′	40·5	2·66	7·70	861
5,000	8° 11′	12° 36′	46·0	3·20	10·40	823

8-*inch R.M.L. Howitzer,* 70*cwt., Charge* 11½*lbs. R.L.G.*², *Projectile* 180*lbs., Muzzle Velocity* 956 *f.s.*

Range, yards.	Elevation.	Angle of descent.	50 p.c. of rounds should fall within. Yards.			Remaining Velocity, f.s.
			Length.	Breadth.	Height.	
1,000	3° 4′	3° 17′	13·8	·32	·79	880
1,500	4° 45	5° 12′	20·1	·52	1·84	858
2,000	6° 30′	7° 16′	26·1	·72	3·36	829
2,500	8° 16′	9° 42′	32·1	·98	5·50	804
3,000	10° 12′	12° 24′	38·0	1·33	8·43	779
3,500	12° 24′	15° 26′	43·5	1·75	12·00	759
4,000	14° 48′	19° 0′	48·6	2·45	16·80	739
4,500	17° 22′	23° 2′	52·9	3·40	—	720
5,000	20° 18′	27° 36′	56·9	4·65	—	709
5,500	23° 44′	33° 24′	60·9	6·00	—	704
6,000	27° 42′	40° 12′	64·4	7·40	—	707

8-*inch R.M.L. Howitzer,* 7*cwt., Charge* 7½*lbs. R.L.G.*², *Muzzle Velocity* 770 *f.s.*

Range, yards.	Elevation.	Angle of descent.	50 p.c. of rounds should fall within. Yards.			Remaining Velocity, f.s.
			Length.	Breadth.	Height.	
1,000	5° 12′	5° 54′	11·1	·49	1·14	723
1,500	8° 12′	9° 3′	16·2	·79	2·40	700
2.000	11° 8′	12° 30′	21·2	1·12	4·72	678
2,500	14° 18′	16° 24′	24·9	1·51	7·63	657
3,000	18° 2′	20° 42′	29·2	2·04	11·40	637
3,500	22° 24′	25° 36′	34·0	2·70	16·40	620
4,000	27° 12′	31° 42′	38·0	3·60	—	609

8-*inch R.M.L. Howitzer,* 70*cwt., Charge* 4½*lbs. R.L.G.*², *Muzzle Velocity* 556 *f.s.*

Range, yards.	Elevation.	Angle of descent.	50 p.c. of rounds should fall within. Yards.			Remaining Velocity, f.s.
			Length.	Breadth.	Height.	
500	4° 24′	4° 36′	4·20	·41	·34	537
1,000	9° 30′	10° 12′	7·90	·83	1·42	522
1,500	15° 30′	16° 54′	11·4	1·26	3·45	507
2,000	22° 30′	25° 0′	14·9	1·71	6·98	493
2,400	28° 56′	33° 12′	17·5	2·07	11·50	486

64-*Pounder R.M.L. of* 64*cwt., Charge* 12*lbs., Projectile* 90*lbs.*

Range, yards.	Elevation.	Angle of descent.	50 p.c. of rounds should fall within. Yards.			Remaining Velocity, f.s.
			Length.	Breadth.	Height.	
500	—	—	—	—	—	—
1,000	1° 36′	1° 52′	6·3	·47	·22	—
1,500	2° 41′	3° 7′	10·9	·77	·70	—
2,000	3° 30′	4° 42′	17·4	1·12	1·56	—
2,500	5° 6′	6° 36′	26·5	1·51	3·10	—
3,000	6° 30′	8° 57′	37·9	1·95	5·88	—
3,500	8° 5′	12° 3′	51·7	2·57	10·17	—
4,000	10° 3′	16° 50′	66·7	3·51	16·10	—

With the 21 cm. (8·24 inch) mortar, 50 per cent. of shots will fall within—

At 1,000 metres, 4ft. 8in. wide and 13 yards long.
„ 2,000 „ 12ft. „ 27 „ „
„ 3,000 „ 21ft. „ 41 „ „

With the 15 cm. (5·87 inches) mortar, 50 per cent. of shots will fall within—

At 1,000 metres,	7ft. wide and	10 yards long.
„ 2,000 „	14ft. 6in. „	17 „ „
„ 3,000 „	22ft. 6in. „	33 „ „

The accuracy tables for B.L. guns must be applied with a certain amount of discrimination. Against anything that stands up visibly to be shot at, and which offers opportunity for correcting the aim by seeing the results, the full accuracy may be counted on. But a great many things interfere with good shooting, such as the weather, the powder, and the nerves of the man who lays the gun. Consequently it may be considered useless to fire at any small object, such as a magazine, unless there be some means of judging of the effect produced. Conversely it is very desirable to avoid marked outlines and visible points in a work, and in every way to disguise its construction, in order to put difficulties in the way of the enemy s artillery.

The use of high explosives in common shell reduces the accuracy necessary for firing against troops, for the shells are broken into smaller fragments and these are projected with a higher velocity to a greater distance than is the case when they are charged with gunpowder.

Shrapnel.—The accuracy of shrapnel shell is of course the same as that of other natures of projectile up to the moment of burst; after this the fragments follow trajectories of their own which are more highly curved than that of the complete shell. The angle of opening may be calculated from the formula $\tan^{-1} \frac{90}{v}$ where v is the velocity of the shell at the moment of burst.

There is a point concerning the accuracy of shrapnel which is worth noting. It is that howitzer shrapnel is more difficult to burst in the proper place for taking effect than that from a gun or from a mortar. The reason of this is that after the burst the bullets go on with a different velocity to that of the entire shell and are subject to a different retarding effect. It follows from this that the laying has to be different in firing shrapnel from what it is in firing common shell. This difference is, however, small with a gun, because the high velocity carries on the bullets nearly in the same line, and is small with the mortar, because both projectile and bullets are mainly under the influence of gravity, but is large with a howitzer where neither of these conditions operate. The use of mortar shrapnel must there-

fore be counted on. Its defects are likely to be want of penetration and excessive spread, but there are possible improvements in the shell which will tend to counteract these.

Penetration into Armour.—Against wrought iron armour the following rule of thumb is nearly accurate. A shot requires 1,000 feet velocity for every calibre of thickness that it has to perforate. Thus an 8-inch shot must have over 1,000 feet velocity to perforate an 8-inch plate, 1,500 feet to perforate a 12-inch W.I. plate, and so on. Steel or steel-faced armour should have one-third added to its thickness to arrive at the equivalent thickness of W.I. armour. Thus a 12-inch steel-faced (compound) plate will resist as much as a 16-inch W.I. plate.

It is, however, very unlikely that it will be possible in a land attack to get a direct blow on armour. The cupolas used on the Continent are of such a curvature that projectiles from guns must glance on striking them. They will have to be attacked with high explosives.

Penetration into Concrete.—The following formula has been found to give very fair results with heavy guns: $P = \frac{E \times \cdot 3}{D^2}$ where P = depth of penetration in feet, E = energy of shot on impact in ft.-tons, and D = calibre of shot in inches. E may be found from the formula $E = \frac{W.\ v^2}{2g}$. There is a want of data to go upon in the case of light and medium guns, but from a round with a 6-inch B.L. in 1880 it would appear that the constant instead of being ·3 must be ·2. Its penetration was 12ft. 6in.

Results obtained at the same time with a 6·6-inch M.L. gun firing a 100lb. shot at 145 yards range with 1,555 ft.-tons striking energy, and attaining a maximum penetration of 8ft. 5in., would give a constant of ·25.

Penetrations into brickwork would be about the same as into ordinary concrete.

A greal deal depends on the hardness of the surface presented to the shot. Judging by analogy from the effects of heavy projectiles, the penetration into a wall built of hard stone masonry would be one-half or even less of what it would be into concrete as experimented upon, and therefore the surface of concrete exposed to be struck should be as hard as possible.

The slowly moving projectiles of mortars and howitzers do not attain any great penetration into concrete surfaces.

At Eastbourne in 1876 a common shell fired from a 10-inch rifled howitzer, weight 355lbs., range 3,000 yards, charge 11lbs., elevation 32°, attained a penetration of 12 inches into a concrete roof.

The penetration of shells fired at angles of elevation between 40° and 60° are nearly double those at 30° owing to the increased falling velocity.

Penetration into Earth.—The distance to which the projectiles of medium guns will penetrate into earth is not a matter of much consequence, since shells must be used to obtain any real effects, but projectiles of about 6 inches calibre may be expected to penetrate from 10 to 20 feet into steep parapets; the least into pure sand and the most into clay.

The penetration of mortars and howitzers is of importance, as they may have to act against casemate roofs covered with earth. The shell from the 8-inch R. howitzer with an angle of descent of 33° 12′ and a striking velocity of 486 ft.-sec. will penetrate from 15 to 20 feet of clay. These distances would be decreased in sand. The same howitzer shell with a striking velocity of 921 ft.-sec. has penetrated 13 feet in sand on an average of several rounds. Against clay the average was 19ft. 5in.

Very long shells (obus-torpilles) fired from the 21 cm. (8·24-inch) mortar at an angle of 60° and a range of 3,000 metres penetrated into sandy earth to the depth of from 13 to 17 feet.

On the whole it appears probable that 20 feet represents the limit of penetration of howitzer shells into earth.

Bursting effect of Shells.—The chief effect of shells which penetrate into concrete is to shake and crack the surrounding mass. The actual crater made by common shell of about 6-inch calibre is not large as a rule, being usually from 18 inches to 2 feet deep and about 4 feet across. The crater does not start from the bottom of the tunnel made by the projectile, but forms a conical expansion of its outer end.

Shells fired from howitzers with low velocities, or at considerable angles with the face of a wall, act against it entirely by burst, and tear off portions of the surface. As the wall begins to be roughened the shells penetrate more and increase the size of their craters. The larger and heavier the shell the greater the effect. It is probable that high explosives will add greatly to the efficiency of this form of attack.

Against earth the effect of the burst of shells is very variable, depending on the nature of the material, whether clay or sand, and on the angle of incidence, as well as on the bursting charge. A 6-inch shell bursting in a clay parapet with a steep exterior slope has displaced as much as 22 cubic yards of soil, whilst against a flat slope of pure sand it will not move more than one-tenth of this amount. An average of several rounds from a 6-inch B.L. gun gives a depth of crater of 3 feet with a radius of 6 feet. The effect varies in proportion to the bursting charge. With an 8-inch howitzer the average crater will be 4 feet deep, with a radius of 8 feet. An experimental parapet of clay 30 feet thick has been cut through to a depth of 4 ft. 6 in. by the 8-inch howitzer in 13 hits, while a similar parapet in sand required 21 hits from the same piece to produce the same effect. The burst of a single 8-inch shell in the middle of the top of a traverse of 20 feet thick will not affect the side slopes.

From this it appears that individual shells will not do much harm to an ordinary parapet, but that if the fire be fairly accurate, any particular gun emplacement, the position of which is known, can be rapidly cut into, and the gun consequently put out of action.

Effect of Shells on Casemate Roofs.—The effect on casemate roofs is due to a combination of penetration and burst, and is of particular interest at the present time owing to the introduction of high explosives. Formerly an arch three feet thick was proof against the ordinary projectiles employed in a siege. Now, such an arch covered with 10 feet of sand has been penetrated by an 8-inch projectile filled with high explosive, and it appears that even an arch 6ft. 6in. thick is not sufficiently strong to prevent fragments being detached from its inner surface. Numerous experiments have been carried out on this subject on the Continent, and some information on it may be found in General Brialmont's work, *Influence du Tir Plongéant sur la Fortification*, 1888.

There are two ways of meeting the difficulty. One, which it is understood has been largely adopted on the Continent for strengthening old works, is to construct over the casemate arch, and separated from it by about 3 feet of earth, another layer of hard concrete from 3 to 5 feet thick, this again thinly covered with earth. The effect is to burst the shell on the first layer and thus to diminish the intensity of the effect on the arch, so that the latter is able to resist. Experiments on a construction of this nature, with a 3-foot upper layer of concrete covered with 3 feet of earth, have been tried in this country with good results. It would probably be better to make the earth covering only 2 feet thick, as it hinders the shells from glancing.

Another method which has given good results here is a roof of railway bars, with 2 feet of concrete and 7 feet of earth over it—the "Twydale" section. This resisted an 8-inch shell charged with high explosive. Some of the bars were slightly bent, but nothing fell inside. The shell was of ordinary dimensions fired from a howitzer, so it must not be assumed that the roof would resist an obus-torpille fired from a rifled mortar. The result was encouraging, but on a further trial a breach was made. It is probable that with 3 or 4 feet of concrete it would have had sufficient strength. A trial has also been made of "steel-decking," covered with concrete. The decking is practically corrugated steel on a large scale, the corrugations being made of various depths from $2\frac{1}{2}$ inches to $7\frac{1}{2}$ inches and of various thicknesses, according to requirements. It acts like a series of trough girders side by side, and is very adaptable to circumstances. It was not so successful as the railway bar construction, more massiveness being apparently required in the ironwork. It may, however, be taken for granted that an iron lining to an arch is a good thing, and so also is a hard layer above an arch separated from it by a soft one; the best proportions desirable are at present somewhat uncertain, but a thickness of 3 feet for each layer would not be far wrong.

The effect of the common shell of field guns against earthworks is so slight as not to be worth giving particulars about. The projectile for these guns is shrapnel, except against buildings. Field howitzers will be used to supplement them where deficient.

Rifle and Machine Gun Fire.—These are classed together as they fire the same bullet, but against fixed objects machine guns will give better results than rifles at the same range. Consequently, the machine gun is well adapted for firing at high angles into a fort, though as a half-inch board will resist the bullet at 2,500 yards it is not very formidable to the defenders. Such fire would, however, be worth while resorting to before an attack. Another use for which the machine gun is well suited is that of keeping down the fire of an individual gun by being laid permanently on it and opening whenever it shows signs of activity.

Effective Ranges.—An effectual bombarding fire can be delivered from a range of about 7,000 yards, which may be increased with some loss of accuracy up to 10,000 yards; shrapnel fire may with skill and care, and with good time fuzes, be used at a range of 4,000 yards; breaching can be effectively done at between 2,500 and 3,000 yards; high angle musketry fire becomes possible within a range of 3,500 yards; machine gun fire is effective at 1,500 yards.

3.—THE DEFENCE.

Object of Fortification.—Before treating of the mode of attack we will proceed to consider how the object of fortification—which is to aid in protecting a certain area of ground from the projectiles and presence of an enemy—can be attained, putting the detailed construction of the works aside for the present.

Evidently the area must be surrounded by a barrier, which he cannot pass without the expenditure of time and labour in breaking through it, and this may be either a natural obstacle, such as a precipice, or an artificial one, such as a ditch; or it may be formed by ensuring that such a heavy fire may be brought to bear on him that he shall be unable to support it. Also it must be protected against the long-range bombarding fire, and this can be done in three ways:—

1. By traversing and bombproofing a sufficient portion of the area enclosed, which can only be completely done when it is of a limited extent, as in the case of a fort.

2. By enclosing an area of such a size that by scattering and concealing the objects to be protected, the enemy may be forced to expend an excessive quantity of ammunition with uncertain results if he tries to injure them.

3. By extending the radius of the line of works, so that the enemy's projectiles from outside them shall not be able to reach the area to be protected.

And in all cases by bringing such a heavy fire to bear, that the enemy's batteries shall be entirely or partially silenced.

It will be observed that the three modes of protection come into play in the case of a large fortress: distance protects the nucleus of the place; the field force, which is necessary for the defence and which must be kept near the front, is dispersed and concealed by the ground; the individual forts have bombproof cover.

Occupation of Ground.—We now come to the important question: How should the ground be occupied by the works, assuming that we are capable of constructing works that will effectually oppose the various modes of attack in use?

The case of a small place is simple enough: a material barrier, suitably armed, may extend all round it. Medium sized places will vary in treatment, and may be best discussed after considering a large fortress, the requirements of which may be more clearly defined.

Works of a Large Fortress.—The first point to take into consideration is that the fortifications of a large fortress must be pushed out to a distance of some 7,000 yards from the town or arsenal it contains; that is to say, if it is an inland fortress the circumference to be defended will be something over 25 miles, and the problem is how to strengthen this line, so as to assist the garrison in holding it.

Now a continuous line of ditch and parapet carried round, while being costly and often difficult to construct, would usually be too strong in some parts and too weak in others, and would also require retrenching, so that passing it at one point should not at once involve the loss of the whole. Moreover, this arrangement does not take enough into account the power of the weapons of the defence, which are sufficient in themselves to prevent the enemy moving over any ground open to a fire which cannot be silenced.

The works, therefore, need not be continuous, and they should depend for their efficiency, mainly, on the fire which can be delivered from them.

A Siege is a Battle Prolonged.—Now a siege is just a battle prolonged to weeks and months instead of hours, and the ground is a carefully prepared battle field. For the operations are similar: the preliminary artillery attack to break down the defence, the approach of the infantry from their first position to that of the enemy, and the final attack, are all reproduced in a siege, with the differences of increased time, of more careful arrangements on both sides, of more powerful weapons, and of a few additional ones, such as mines.

How then is a defensive battle field to be taken up? Not with a continuous line of men in equal numbers all along the front, but with men most concentrated on the points from whence they can best deliver their fire, or on those which it is easiest for the enemy to attack; the keys of the position strengthened by field works; positions found from which the artillery can act with effect, and batteries thrown up there for the guns; obstructions placed where they will not interfere with the movement of the troops of the defence; and the ground cleared for firing over.

All this has to be reproduced in a fortress in a permanent form, and with that added strength that can be given to permanent structures.

One should look at the ground with the eye of a General, so to speak, and say: "This is the key of the position, and here must be my strongest work which the enemy will be forced to attempt to capture. There is the point from which my heaviest guns should fire at his batteries, and I must build a battery there which he cannot entirely silence. From that hill the ground can be swept for thousands of yards; some well protected guns in a work there will force him to take it before advancing any further." And also one should say: "That gap of 4,000 or 5,000 yards between my works need not be filled up with permanent fortifications; it is swept by fire that will take days to silence, giving me plenty of time to strengthen it with field works;" or: "It leads to nothing; the enemy would not be bettered if he got there, for he would find no position to hold and would be compelled to go back again."

The Works required are varied.—It will be seen that the works required in a modern fortress are of a varied character, as they have to fulfil different objects, some being intended to provide for direct fire, some for flanking, some for close, some for long range fire; some perhaps being mere obstructions which need give no fire at all; some having to hold out against the attacks of the enemy to the very last; some not likely to be subjected to a close attack at all.

Influence of the Garrison on the Design.—All these considerations must be weighed in making the designs, and, moreover, the number and quality of the troops likely to be used in the defence must be taken into account. If they are few in number, the flanking and short-range fire must be developed and secured, so as to aid in closing the intervals between the works, and there must be no extension of the defences that is not absolutely necessary. There are usually points in advance of the main line of defence, which, if held for a time, would much retard the enemy's operations, but this can only be done with a strong garrison or by an able commander, who can make up for other deficiencies by his own skill.

With a numerous garrison, the flanking fire of the works is of lessened importance, as the Field Force—that is, the the troops which act in the intervals between the forts—would be well able to protect itself with the assistance of temporary works. Probably some reasoning of this kind must have led the Germans to build long shallow works with hardly any flanks. They are only suited for delivering direct fire.

With a garrison of indifferent quality, the works require to be numerous and close together, so as to give more mutual support than is required with first class troops, and obstructions may be multiplied, so that less work will be thrown on the field force.

Nature of English Garrisons.—It is hardly necessary to observe that the garrisons of our fortresses are never likely to be numerous. Moreover, the quality of the troops is not likely to be at all homogeneous, but made up of Regulars, Militia, Volunteers, and Reserve men, and though there is no doubt about the fighting qualities of any of them, yet it would not be safe to trust much to a field force of such composition until it had time to get organized.

This would be the condition of the home fortresses; the large places abroad would probably be worse off in the way of numbers, better off in the quality of the troops; small places everywhere may be deficient in both.

Luckily the defence of a detached fort is a job which is suited to the English characteristics; it is something like commanding a ship, and the isolation of works, which other nations look on as one of the defects of modern fortification, is likely to bring out the best qualities of our men.

Nature of English Forts.—We are thus brought to the conclusion that English forts should be well provided with flanking fire; that each should be strong in itself, not dependent on external aid, and that they should be somewhat more numerous than theory would demand, considering the power of the weapons only.

Number of Works required for a Place.—It is obviously impossible to lay down the number of works required for a place of given circumference, as it depends entirely on the conformation of the ground; but the minimum number required in any given case is determined by the consideration that they should be sufficient, in conjunction with any Field Force allotted to the place and likely to be found there on the outbreak of hostilities, but without any intermediate temporary works, to prevent the enemy marching into the place without having to silence any of them.

This for a fortress is the equivalent to the making a fort secure against escalade; it ensures that the enemy shall not capture it before there has been time to prepare for him, and we thus arrive at a principle on which the minimum number of works necessary to be constructed in a permanent form for the defence of a place may be determined.

Any works in addition to the number required for this purpose form a preparation for resisting a siege.

With a given sum of money with which to fortify a place, the fewer forts there are the stronger each can be made, and it is a saying that still holds good that a "small fort is a weak fort," so a multiplication of works is to be avoided.

The works built in the first place will naturally be the key forts and the flanking forts; that is, the forts which occupy points which

are tactically important, and the retention of which is vital to the defence, and the forts which, by their position enabling them to see long portions of the line, can sweep them with an effective fire, and thus prevent the enemy passing.

In addition to these there may be points well suited from their command or saliency for delivering a fire on the enemy's approaches, but which could hardly be occupied in a temporary manner on account of a heavy fire that could be brought to bear on them. These then must be occupied by permanent works, designed so that their guns may not be easily silenced. Such positions are not likely to be required at the present day, as the long ranges of guns and the use of howitzers for curved fire gives a large area for choice of sites for them. Permanent batteries will, however, be built in sites concealed from the enemy, and the guns directed by observation.

Occasionally, too, places are found over which it is most desirable that the enemy should not pass, but which are not suited for firing over. Here permanent obstacles may be formed. These four forms, therefore, include the various permanent works that should be built.

Intermediate Batteries.—But a great deal of the work of the defence during a regular siege must be done from temporary batteries erected in such spots as may become suitable during its progress, or from the permanent but strong and, if possible, concealed works distinct from the forts; for just try to realize the condition of an important fort of the type in vogue up to the present time after the enemy has armed his breaching and counter batteries and opened fire.

Condition of a Fort under Fire.—In the first place you cannot see any of the breaching batteries. They are a mile or two away, hidden behind hedges, woods, or hill-sides; all that can be distinguished of them is a light cloud of smoke every now and then rising behind the trees; a shrieking sound is heard, and you catch sight of a big howitzer or mortar shell plunging down at your escarp or into the parade. You see from the puffs of smoke that the batteries are spread laterally over a mile or more of country, and that projectiles from this large arc are concentrating on the fort. Even the assistance afforded by the puffs of smoke is likely to be, shortly, a thing of the past, when smokeless powders are in use. A few guns may be firing at your artillery with shells, which are flying so swiftly that you do not hear them till they are past you. Added to this, every now and then there is a pattering of rifle bullets about the parade from a machine gun somewhere in the trenches, firing at a long range and high angle.

As to the fort itself, one can see from the caponier that the escarp is beginning to get knocked about with the fire of the heavy howitzer shells, and the roof of the caponier itself has had a bad hit or two. The face of the parapet is decidedly out of shape, especially where a howitzer battery has begun cutting a way into one of the gun emplacements; that must be stopped, if possible, and the gap filled up at night.

Inside, the parade is all holes and heaps of rubbish from exploding shells, and all favourable slopes have been taken advantage of by the garrison to build bomb-proof shelters.

Now, is there any good in attempting to work guns in such a place if it can possibly be avoided?

At a later time in the siege, when the attack has got much closer up, it may be necessary for the fort to fire occasionally with light guns at the approaches, as it may have some command over them which the ground outside has not; but in the middle period of the attack, when the enemy's works are still some distance off, there is no good to be got from working the guns in the very hottest place of all when they will be equally effective if removed from it.

Intermediate Batteries.—The besieged, therefore, should dispose the guns for resisting an attack in batteries thrown up in the intervals between the forts.

A further advantage thus gained is that, in addition to the breaching and counter-batteries for firing on the forts, the enemy will have to provide counter-batteries to subdue the fire of the outlying batteries of the defence, and to expend additional ammunition in doing it, thus increasing his transport requirements.

Also, the difficulties of doing this will be added to by his ignorance, to begin with, of the exact position of the temporary batteries, and by the power of changing their position if he does get the true range.

We see, therefore, that while the guns in the forts may be used in the first period of the attack if there are no others mounted, and in the last period of the attack because the fort may then be the best place to fire from, yet in the middle period the guns should be as far as possible outside.

This, of course, does not apply to works which are constructed in places which are eminently adapted for guns for direct fire, but where the position of the battery is necessarily defined and must be

known. In such a case a permanent work, with all the devices in it that can give security to the guns, should be built, and the guns worked in it. This is the third class of permanent work mentioned before.

The intermediate temporary batteries will either be of the usual siege type, armed with guns mounted on siege carriages of various patterns, or will be arranged to suit guns worked on railway trucks.

Disposition of Armaments.—In our large fortresses the armaments have been arranged in accordance with these principles.

The flank guns will all be mounted, and also some of the guns on the faces, as a "ready" armament to meet any attempt at an assault, and to hinder the operations of the investment.

The remainder of the guns and all the rifled howitzers will be kept in the fortress, with their siege carriages and platforms of various patterns, ready to be moved out to the intermediate batteries when the place is prepared to stand a siege.

4.—THE ATTACK.

The Attack.—The methods of the attack have not been materially changed by the introduction of rifled guns, although the area covered by it has been enlarged according to the power of the weapons, in the same manner in which the fortresses have been enlarged.

It is not necessary here to do more than recall to mind the general features of the operations of a besieger, as, for instance, they are described in Major Fraser's R.E. Prize Essay for 1878 on the *Attack of Fortresses*, and in the writings of the numerous authors whom he quotes, and to mention some of the modifications since proposed in order to meet the improvements in weapons. Then, in considering the designs of permanent works, all the forms of attack which they may have to meet can be provided against.

Modes of Attack.—There are five modes of attack—

1. Blockade.
2. Surprise.
3. Assault by open force.
4. Bombardment.
5. Regular siege.

Blockade.—In a blockade the besieger will not meddle with the defences, but will keep out of range of the guns and entrench his position.

If any attempt is made to delay the investment or to break the line from within, it must be done by whatever force may be available when a sufficient garrison has been left to secure the works against assault.

In a fortress occupying a position of strategical importance, where the power of moving out should, as far as possible, be retained, precautions must be taken against blockade, or there will not be much chance of breaking it. The works should be so placed that they can command the country a long way in advance, there should be free communication about the interior of the fortress and to the front, and it should be so arranged that the movements of troops in the interior cannot be seen from the outside.

Surprise and Open Assault.—Surprise and open assault are those forms of attack against which permanent works should always be in security; it is the great advantage they possess over field works, whose ditches are seldom of much use as obstacles, and whose fire is entirely from open parapets.

An assault would most likely be undertaken after the place had been invested, and some siege works and intrenchments constructed, so that the besieged might be occupied along the whole circuit of the fortress; also, that the assaulting party might not have to begin its advance at a very long distance; and that, if repulsed, the besieger might still be in a position to check the enemy, and to proceed with the operations of a regular siege.

Probably a preliminary fire of artillery would be employed so as to injure the works, more especially their flanking defences.

Open assault has been advocated lately as a preferable means of attack, to be made at the earliest possible opportunity; that is to say, the attack should be made on a fortified place as against troops occupying a position in the field. It is very possible that this might succeed against small places, which would be enveloped by a fire to which they could not adequately reply, and against places with insufficient garrisons, or those which had not prepared themselves against a siege. This might very well be the case with some of our fortresses. It is essential that their main works should be "storm-free," and when uninjured, capable of defence by a small garrison.

These modes of attack are not likely to be adopted against a strong garrison; nevertheless, the works should be prepared to resist them, and surprise must be continually guarded against.

Bombardment.—Bombardment is a mode of attack that can be undertaken hurriedly, and while the investment is still incomplete;

but it is one which is not likely to have much effect, except on the civil population, who may be frightened by it into putting pressure on the Commandant to surrender.

It might be met either by a sortie, if there be enough troops available, or by returning the fire from the fortress, or by getting under cover and letting the besiegers waste their ammunition as much as they like.

Regular Siege.—A regular siege is the form of attack which the strongest works are designed to resist as long as may be posssible for them. It is, however, one to which our works are not likely to be subjected, as is pointed out in the introductory section of this chapter. The preliminary operations might be carried out, but it is improbable that the approaches would get beyond the first artillery position.

Investment.—The operations would begin by the investment, commenced with cavalry and light artillery, and completed by all arms.

This operation might be resisted by any disposable troops within the place, but cannot be seriously checked, unless they are not far inferior in strength to the enemy. Attempts should be made to push the investment line back as far as possible by the occupation of points some distance in advance of the line of works, and thus to delay the commencement of the siege works. These points would have to be assaulted and taken, but a very determined resistance is not to be expected, as on the defenders' side it would be a sort of rear-guard action, in which the troops are expected eventually to retire, and in this case without incurring too great loss.

If the operations of the investment, however, be unduly prolonged, the defenders may make some of their advanced posts so strong as to be capable of resisting a hasty assault, and to require pounding with artillery for their reduction, in which case they may be considered outworks of the main line of defence.

Eventually, though, the defenders will be driven back until they come under the protection of their heavy guns mounted on the works, when their outposts may be as far as 1,000 to 1,500 yards from the place.

Line of Investment.—The attack will now form the line of investment, which will be entrenched with outposts in front, and which can hardly be nearer than 3,000 yards to the works.

The exact position will depend upon the accidents of the ground It is seldom that the guns of a fortress have an unrestricted field of fire up to the limit of their effective range; there is almost always some features of the country within that range which will give cover to the assailants, and from which the real attack will commence. This should be well known to the defenders, and they may be able to annoy the besiegers, and, perhaps, to delay their operations, by firing at points where they are likely to have men concentrated, or where the communications may necessarily come into view.

Preparation of the Siege Works.—At this stage of the proceedings there is likely to be a cessation of the forward movement for a time, while the besiegers are strengthening their position, preparing their plan of attack, and bringing up their siege guns and *matériel*. They also have to provide shelter for the troops, to complete the communications round the place, and to arrange the artillery and engineer parks.

This is the time at which an assault is likely to be attempted, if made at all. If successful, a great deal of this labour would be saved, and the defences are not likely to be in such good order as they would be a little later; for the besieged should profit by this lull in the operations, and improve their works, and construct any fresh ones that they think desirable. Any bombardment preliminary to an assault would have to be made with field and position guns; the use of such guns for that purpose would give the besieged a hint as to what might be expected.

At this period of the siege both sides would be reconnoitring, and field observatories and captive balloons would be used. There is no doubt that the use of captive balloons will be much resorted to in future sieges. Works of the modern type, with long flat slopes, will be very visible from a balloon, although admirably adapted to concealment from points nearly at their own level.

First Artillery Position.—If an assault be not made, or be unsuccessful, the batteries of the first artillery position will now be constructed. These may be about 3,000 or 4,000 yards from the place, and will be first used to bombard the defences, so as to reduce the amount of their fire. As these batteries will generally be hidden from the defenders during their construction, they can be carefully built; and it will be worth while doing this, as many of them will remain in use to the end of the siege.

It is not improbable that a sortie in force would be made from the place at this time. The destruction of the completed siege batteries, and rendering useless their armament, would be an object well worth attempting, and there would be an advantage in doing

it now, before the fire of the forts has much diminished, and while a good deal of ground in front of them is still held by the defence.

It has been pointed out that a great advantage would accrue to the attack if fire were opened from the guns of the first artillery position, immediately after the completion of the investment. To do so would require careful organisation and a good deal of work to get the siege train up to the front, but it would probably catch the defence unprepared, and might render dismounting many of his guns unnecessary by preventing them from ever being mounted. It should always be kept in view as a possibility.

Driving in the Outposts of the Besieged.—Under cover of these batteries of the first artillery position, the attack will push back the defenders to within effective musketry range of their works, say to from 800 to 1,000 yards, the troops establishing themselves in shelter trenches, or behind any cover that they can find, which would not be much if the ground has been properly cleared.

It is probable that a sort of rude system of approaches and parallels will grow up during this advance; trenches would be thrown up along the most exposed parts of the communications, and the shelter trenches and rifle-pits occupied by the outposts will form a tolerably continuous ring.

The light artillery of the defence will probably find opportunities of usefulness during this period, principally in firing at the enemy's troops when uncovered or but slightly protected. It would avoid injury from his heavy artillery by its mobility. It would not, as a rule, be used within the forts, as they at this time are made the special objects of the enemy's fire, with a view to silencing them.

At this stage the further details of the advance can be settled, and it must now be definitely directed against those forts which it is desired to capture.

As a rule, in attacking a chain of forts, it will be necessary to take two, and to silence the two that flank them, in order to make a gap sufficiently large for penetrating to the attack of any interior works. With forts at large intervals it may be only necessary to take a single one.

Against the forts which it is intended to take, a system of parallels and approaches must now be directed, which will be continuous or not according to the nature of the ground.

First Parallel.—The first parallel will be about at the limit of aimed musketry fire from the works, say between 700 and 1,500 yards off. If the defenders have been able to hold any works pushed out in front of the forts, they will force the parallel to be opened by so much further off from the latter; but the besiegers will, of course, endeavour to deprive them of this advantage by attacks on the outposts, and by artillery fire from the first artillery position. Still it will be difficult to drive troops out of musketry trenches made only 200 or 300 yards in front of the forts.

The first parallel will be made by flying sap for the sake of rapidity, for the besieger will conceal both the time and the place of its construction; the time, by attacks on the pickets of the defence on several nights previous; the place, by these attacks being made at various points besides the one decided on for the approaches.

The defenders will find it very difficult to discover these operations, but as they must have some idea of when they are likely to come off, they will then redouble their efforts to find out what is going on in the enemy's lines, by scouts, by spies, and by illuminating the ground by various means at night. The discovery of the parallel actually in course of construction would enable them to inflict great loss on the beseigers' covering and working parties, and might even necessitate a change in the plan of attack.

The construction of the first parallel will be facilitated by the shelter-trenches and rifle-pits, which must have been made by the outposts.

The parallel having been made, it will be connected by proper approaches with the rear.

Proper protection must also be provided for the guard of the trenches, and a good deal of it must be bombproofs or covered trenches.

As soon as all this is completed, it will be almost hopeless for any sorties to be successfully made against the front of the parallel, but they might be directed against the flanks, which will have to be retired in echelon.

Second Artillery Position.—When the first parallel has been made as complete as is wished, the batteries in the second artillery position may be taken in hand. They would be about 1,500 yards from the fortress, and most probably covered by the first parallel. They must be few in number, for the difficulty of protecting the guns at such a short distance will be very great, and, besides, most if not all their work can be done from the longer ranges. Still for counter-battering parapets, and destroying the gun emplacements and bomb-proofs on them, the increased penetrative power to be got by a de-

crease of range would be valuable. It will be necessary to mount the guns on some form of disappearing carriage, if indeed they can be brought up into this position at all.

The besieged will probably endeavour to meet this fire with light and Q.F. guns, brought out for a short time from under cover; and with curved howitzer fire from some retired batteries.

The latter will have to be searched out, and replied to, by howitzer fire from the first artillery position.

In conducting an attack against one of the Continental fortresses, largely provided with cupolas to protect the guns, it will be a matter of great importance to minimize the size of the works to be executed in front of the first parallel. It will probably be difficult to silence the guns within the cupolas, but their value to the defence can be reduced by giving them little to fire at. The armour piercing power necessary for the guns of the attack must be obtained by using heavier weapons at the longer ranges, rather than by bringing lighter guns up closer.

Against our present works there would be no necessity for a second artillery position at all.

The Advance from the First Parallel.—The besiegers must now endeavour, as soon as the enemy's fire is sufficiently subdued, to carry their approaches up to the counterscarp of the work they are attacking, so as to be able to bring up the men in safety to the assault of the breach.

This will be done by parallels and zigzags, executed as far as possible by common or flying sap, and afterwards by regular sapping.

The most advanced approaches will be either ordinary double saps or short zigzags, so that progress may be as direct and, consequently, as rapid as possible.

The excavation will have to be deep to get cover against the bullets from wall pieces and curved fire from distant batteries, and it may even be necessary to resort to mining.

It will be necessary to blind portions of the trenches, so as to get overhead protection, and to obtain sufficient traverses for the remainder. Steel sap shields and such devices will have to be used.

The difficulty of this part of the work will be greatly increased by the use of high explosives in shells, against which hasty works could be made proof with difficulty.

It will be a great thing for the besieged at this time if they can get a light gun into action, as it must stop the sapping. It is probable that some of the Q.F. guns will in future be employed under these circumstances. The rapidity of their fire, the ease with which they are worked, and the small number of men they require, make them particularly suitable weapons.

Similar weapons will be used by the attack to keep down the fire of the defenders.

Crowning the Counterscarp.—If there be no countermines, the crowning of the counterscarp will be completed by sapping the escarp breached by artillery fire from a distance, and the ditch approached either by galleries down to and through the counterscarp, or by a ramp formed by blowing in the latter with a large charge. If there be no revetted ditch, but instead a broad band of obstacles, they will have to be removed by some means before assaulting. It might be simpler to envelope the work and to storm the gorge.

War of Mines.—If there be countermines, which there most probably would be, the trenches must stop short of the defender's galleries and the war of mines will commence.

The besiegers will either fire very large charges to destroy the countermines, and to form lodgments from which to make a further advance, or they will attempt to cut off the defender's galleries, by forming a hasty lodgment over them and firing charges at the bottom of shafts sunk from it.

Whatever method be adopted, the war of mines is nearly certain to end in favour of the besieger, though it may be much prolonged by a skilful defence.

Destruction of the Flanking Defences of the Ditch.—On arriving at the counterscarp it will be necessary to deal with the flanking defences of the ditch; if these be counterscarp galleries they will be mined into from the back; if a caponier, and it has not already been breached, it may either be blown up by a gallery carried under the ditch; or smothered, by having the counterscarp blown in upon it; or may have the end wall blown in. This may be done either by carrying a blinded gallery across the ditch to it, and thus placing a charge, or by means of guncotton laid against it in the open, as soon as the ditch is accessible to the besieger.

If it consist of turrets for Q.F. guns, their foundations might be laid bare and cut into by howitzer shells from a distance.

No form of ditch defence can last long if the besieger can break through the counterscarp close to it.

Breaches.—Before the works for crossing the ditch are completed,

one or two breaches should be formed in the escarp if one exists. They should be from 30 feet to 60 feet wide.

With good rifled howitzers and careful firing they could be made either from the first or second artillery position, but the first allows of larger charges being used and enables higher terminal velocities to be obtained with the projectiles, and is also more secure.

Assault.—The breaches having been made, the descent into the ditch completed, and the flanking defences destroyed, the assault must be delivered, preceded by a heavy fire from all the guns to clear the heads of the breaches.

Further Operations.—The work having been taken will, if a detached fort, become a base of operations for a further attack against the enceinte, which, if the latter be strongly constructed, will have to be carried out in a similar form to that already described.

5.—DESIGNS OF WORKS.

Before discussing any further the disposition of the fortifications around a place under various circumstances, it is advisable to consider in some detail the nature of the works that would be built; and as a fort in a key position should combine in itself all the possible good qualities that a fort can possess—since it must be secure against open assault; must be able to use any guns it possesses effectively, both at long and short ranges, both to the front and to the flank; and, in addition, must contain secure accommodation for its garrison, ammunition, and stores—the design, therefore, of a good key fort must exemplify all the requirements of the other classes of permanent works, and in describing one most of the details necessary for all will be described at the same time.

Design for a Permanent Work.

It has been stated in the introduction that the intention in this book is to describe such works as are actually constructed, in order that the information given may be of practical use. Unfortunately, in the case of permanent land forts, it is necessary to abandon this rule, as there is not that consensus of opinion on the best form to adopt which there is in the case of coast batteries. This is due to there having been so little construction of land forts in England of late, while a great deal has been done in the way of coast works. Continental practice has not helped us much, as the works there are intended to meet a kind of attack different to that to which ours are likely to be subjected. In many cases iron has been largely used in a manner which all are agreed is unsuited to our requirements.

Having, therefore, no examples to go to, I designed a work which might serve as a type of the most powerful class of fort that we might require. This was submitted to the criticism of various officers whose opinions on the subject carried weight. Their views, however, were generally so unfavourable to many of its details that it was perfectly clear that it would not do as a model of what would be acceptable in a design. Still, there was nothing to take its place, and as I held to my own views as to several of the points in dispute, it was doubtful what was the best course to pursue.

Finally I decided to reproduce a drawing and a short description of a certain infantry redoubt, which is a work that everyone admits is the starting point of all our modern designs.

Then to give my own design, with notes on the points in dispute. It will serve for a warning, if for nothing else, but I am sanguine enough to think that in some cases my opinion may eventually prevail. It will at any rate serve as a collection of drawings of details of fortification out of which bits may be picked to compose into other designs.

Lastly, I propose to give a drawing of a fort for the same site, which will represent to the best of my ability the views of my critics.

Conditions Governing Design.—It is considered that the following conditions govern the design of English land works:—

1. A fortress should be looked upon as a series of positions for troops, strengthened by works, surrounding an area to be defended. It should not be considered as consisting of a ring of forts, though it will often assume that shape. The former conception puts the troops in their proper place as the primary factors of the defence, and it gives greater freedom of design.

2. The points of tactical importance should be occupied with works strong enough to secure them against any attack likely to be made. What this attack may be varies according to the locality, and, consequently, the works should vary in strength.

3. The four forms of attack on a fort besides blockade are surprise, assault, bombardment, and regular siege.

Against surprise the safeguards are watchfulness, a material obstacle, and the power of resistance with a small garrison.

Against assault the same; together with the power of developing a heavy fire over the near ground. This, at the present day, means the power of utilizing a large number of rifles and machine guns.

Against bombardment secure bombproofs, and forms of construction not liable to be injured in a manner which may be difficult to repair.

Against regular siege the same; together with the power of resisting actively the various stages of the attack by sorties, artillery, musketry, and mines. Only the two latter means are essentially connected with the fort itself.

A regular siege, carried out with heavy guns and all other appliances, is most unlikely to take place against an English fortress. The earlier stages might, however, be entered upon with the aid of position artillery, field howitzers, and mortars, in order to test the power of the defence. The attack would, of course, be pushed home if the latter proved weak, and it appeared likely that the affair could be rapidly concluded.

4. The guns and howitzers intended to oppose the batteries established as a preliminary either to a bombardment or a regular siege should be placed in the intervals between the forts.

This utilizes from ten to twenty times the length of front that would be available if they were put into the forts; enables the guns to be partly, and the howitzers completely, concealed; and reduces the fire aimed at the forts. Directing the fire, however, becomes more difficult, and as the forts will occupy salient and commanding positions, and will be the objects of the attack, this directing should come from them, and means should be provided for carrying this out.

5. It is useless for a fort to occupy a position tactically of importance to the defence, unless it can make its influence felt over the surrounding country against troops in the open. Assuming that the forts will be at about 5,000 yards interval, an effective fire of musketry and of shrapnel up to about 2,500 yards from them would be sufficient, but it is desirable that they should be able to fight up to longer ranges. At the beginning of a siege, moreover, the forts may be the only works in existence, and they should, therefore, be capable of defending the fortress as well as themselves individually against assault. The forts should, therefore, contain artillery capable of fire to the front.

This is strongly denied by many. It is considered by them that there should never be any guns in the forts except possibly in the flanks, and that all artillery fire at all stages of the attack should be delivered from the intervals. Though I do not agree to this, it may be seen from paragraph 4 that I should move them out at an early period of the siege.

Except as to the desirability of putting the guns in the forts, these conditions would be very generally agreed to. It is not certain that the first would be accepted by everyone, but I am convinced that it is the right way of looking at the matter.

Notwithstanding this agreement on the main principles involved, it seems, at present, impossible to design a work which shall satisfy everybody. Consequently it is proposed, as said before, to give three designs, which will at any rate form a basis for further developments.

Infantry Redoubt.—First for the infantry redoubt. The description of this is extracted from the paper on *Semi-Permanent Infantry Redoubts*, by Major G. R. Walker, R.E., which appeared in Vol. XI. of the *Professional Papers*, in 1885.

"The conditions to be fulfilled were considered to be :—

"(*a*). The greatest possible development of musketry (including machine guns) fire from the redoubts, combined with the best possible obstacle to assault, efficient cover for the defenders, and the minimum exposure of the work to distant view and fire.

"(*b*). The maximum amount of protection for the batteries outside, both by musketry fire from the redoubts, and by the provision of an obstacle sufficient to protect them from assault.

"The fulfilment of condition (*a*) was sought for by :—

"1. Tracing the redoubt in the form of a long and narrow oblong, with the corners rounded off; the length, in any particular case, to be adapted to the proposed garrison; the whole of the parapets, unencumbered with guns, being available for musketry fire; the width so designed as to afford, in plan, as small a mark as possible to the enemy's fire, while allowing sufficient space for the bombproofs required to shelter the garrison. The section given in *Plate* III. shows the least depth that is considered suitable. The cover for the garrison, constructed as shown beneath the parados, is primarily intended for the shelter of the men in action, but it also affords cover from the inclemency of the weather. In winter the casemates may be temporarily closed in rear with any materials which are available, and stoves might be added; but no attempt has been made to provide permanent barracks fitted with all the requirements of civilization. The troops would, as a rule, live in tents, or otherwise, outside the work, in rear, and the work need only be fully manned when attack

was anticipated; and as, for such a position, an outer reserve would be indispensable, this arrangement would present no difficulty.

"2. The profile is arranged so as to get rid of all dead spaces in the ditch, and to bring the material obstacle to assault under direct fire from the parapet, while effectually covering it from the enemy's artillery fire. The section will show that this is done by prolonging the superior slope of one-sixth to the front (in the form of a glacis), until it reaches a depth of about 10 feet below the natural level of the ground, and by placing in the ditch thus formed an iron palisade, leaving the counterscarp at the natural slope of the earth, and constructing a small glacis to increase the cover for the palisade. Inside the work there is a good shelter behind the front parapet. The parados, which is of the same height as the crest, and has a gentle slope in front, affords cover to the bombproofs, which are protected against high angle fire with iron rails, two feet of concrete, and about five feet of earth; the rear parapet is kept as low as is consistent with its obtaining a view of the ground in rear, in order to make the most of the protection afforded by the parados.

"The command of the whole work is reduced to the minimum, consistent with the defence of the ground in front by musketry fire, with the object of rendering it as inconspicuous as possible.

"The fulfilment of condition (*b*) includes :—

"1. The protection of the batteries by the fire of the redoubt. On this point it is only necessary to say that their defence, supposing the maximum development of musketry fire from the redoubt to be attained, depends solely on the full exposure to fire from the redoubt of the batteries themselves, and of the approaches to them, and is, therefore, simply a case of judicious adaptation to the ground for a given site.

"2. The protection of the batteries, by means of an efficient obstacle, against sudden assault, seems to be of sufficient importance to demand, not only the preparation of field obstacles, as far as may be possible, when the necessity for defence arises, but also the extension in front of the batteries of the iron palisade proposed for the redoubts, and this more especially in positions where natural obstacles do not exist, and the means of creating abatis, etc., are not at hand."

The complete scheme for occupying the position where this redoubt is placed includes the use of two of them, each about 300 feet long internally, placed 1,350 feet apart from crest line to crest line, with a sunken battery for guns and howitzers between them. In this form the defence is strong as the ground lends itself to the arrangement, but it is undoubtedly a defect to have to divide the garrison of the position into three separate parts.

The weak part of the design is the absence of any protection for the men at the parapet against high angle shrapnel fire from howitzers or rifled mortars. Light traverses, which would check the dispersion of fragments from shells filled with high explosive, could be easily added.

If the redoubt be used as an independent work it is deficient in length of parapet as compared with its exterior perimeter. It would seem quite possible to push an attack to the crest of the counterscarp in the same way as against any field position, keeping down the fire of the defence by the superior quantity of that of the attack. On arriving at that point some could descend into the ditch and clear away the railing while the fire was kept up over their heads. It is certainly necessary to have additional obstacles on the glacis. A shallow ditch with a wide band of barbed wire entanglement has been advocated. This, however, would not be so well protected against shell fire, and might be crossed without being actually destroyed.

Fort designed for Darland Hill.—Next comes my own design for a fort, and as I dislike "type" forts, which are suited to no place in particular, I have adapted a design to the ground at Darland Hill, at Chatham, which requires a first-class work, and which is of very varied contour, thus introducing several conditions to be met. See *Plates* IV., V., and VI.

Darland Hill being on a salient of the line of defence, and thus requiring a development of flank fire, the work is deeper from front to rear than would be desirable were it forming part of a line of flatter curvature.

Main Parapet.—The form of the fort is mainly governed by the organization of the main rampart for artillery. It is arranged for four 5-inch B.L. guns on 6-feet parapet lattice-girder siege carriages. These guns would be, preferably, mounted on HP. siege carriages if they are introduced into the service. Each gun is provided with space for a double-decked platform giving 90° training, with a low traverse on its outer flank, and with a ramp at 1 in 7 leading straight from the pivot to the mouth of a casemate made for its reception. The height of the parapet is such that a man in the centre of the road in rear of the rampart is protected from shot coming straight over the crest at a drop of 1 in 4.

Satisfying these requirements results in a "unit of parapet," and fitting these units together so as to command the necessary field with artillery fire results in the main parapet shown in the plan.

As much musketry parapet as possible is added to the "units," and a small cartridge store and a shelter for men and stores placed below. The centre section of the parapet and the shoulders, right and left, are devoted to musketry and machine guns.

The main parapet acts on the ground outside the crest of the glacis.

It will be seen that many variations of the organization of the rampart may be made by changes in the conditions, such as the direction and slope of the ramp, or the dimensions of the traverse.

In order to have a parapet inconspicuous, and difficult to injure by projectiles, the external slopes are made very flat.

Lower Parapet.—In front of the main parapet, below its line of fire, and just above the crest of the glacis, is the musketry parapet for the defence of the ditch. The slope in front of it runs evenly down to the bottom of the ditch, and is protected by an iron palisade with a wire entanglement within it. This parapet allows of a very large development of musketry and machine gun fire in case of an assault, and might be counted on as being available even at the end of a siege, but in order to admit of the place being defended by a small number of men, and for other reasons, six 6-pounder Q.F. Nordenfelt guns are added. These guns will fire case shot over the whole of front ditch. Also their shrapnel fire is effective up to 2,500 yards, and they thus afford a means of commanding the ground between the forts, which is essential to the defence. They are not arranged to sweep the glacis, as it is thought that this can be done sufficiently with musketry and machine guns from the main parapet, and they can thus be better concealed.

The 6-pounder guns are shown mounted in small steel "tourelles," six feet in diameter, and about one foot six inches high, designed by the Maxim-Nordenfelt Company. Being so small, they can easily be concealed. They are said to be proof against field guns. "Disappearing tourelles" for the 6-pounder Q.F. guns were originally introduced into the design, but the others have been substituted for them, as they are simpler, and also can use a longer and, therefore, a more powerful gun.

I do not consider that a satisfactory strong modern fort can be constructed without "tourelles" of some pattern for guns of about the power of the 6-pounder Q.F.

The communications with the "tourelles" form bombproof shelters for the men allotted to the defence of the lower parapet.

Ditch.—A revetted escarp is not used, nor a detached wall, but their place is taken by a railing and entanglement. It is thought that the value of masonry is not commensurate with its cost; it is easily injured, and if flanked requires special works for this purpose only. The ditch is a shallow one, intended to cover the railing, and to form a way of communication for guards and pickets, and to be a starting point for mines if required. The centre part of the counterscarp is revetted as a shelter for men and stores.

A covered way is carried round the crest of the glacis. This would serve as a patrol path, and as a shooting line if wished. It is not intended that this should be manned by the garrison of the fort, but by a detachment from the field force. Their line of retreat would be clear of the fort, not into it.

Land mines and entanglements might be advantageously used on the glacis.

Look-out Places.—Reverting again to the main parapet, look-out places are provided on either flank, so that the fort may discharge an important duty in directing the fire of the defence.

The look-out place should be armoured like the "tourelles," and be provided with a map properly prepared for rapidly ascertaining ranges, such as is now in use by the artillery in land works. It should be connected by speaking tube with the three "tourelles" on its own flank, and by telephone with the intermediate batteries.

The Gorge.—The gorge of the fort is closed with a row of casemates. Over them is a light parapet protected by a heavy parados. This parados, being higher than the crest, gives a sky line for the front parapet. This last function might, however, be done as well by bushes, and does not necessitate raising the earthwork if not otherwise required.

A central traverse helps to localise the effect of shells, and contains a passage running from the entrance to the front parapet. On either side are bombproof quarters for officers. Below is a magazine, where a supply of ammunition can be kept for the guns of the intermediate batteries.

Under the counterscarp of the gorge are store rooms and atrines

There is no drawbridge, but the approach is obstructed by plated and bar-iron gates.

Garrison.—The fort could be held by about 100 men, for whom there is ample accommodation. More would be desirable during a

regular siege or a determined assault. There is room for about 750 riflemen on the banquettes, but it is not supposed that all the parapets would be manned at once.

Armament.—The armament would consist of:—

Four 5-inch B.L. guns on lattice girder or on H.P. carriages.

Six 6-pounder Q.F. guns in "tourelles."

Twelve Maxim machine guns on parapet mountings.

Objections to this Fort.—The objections made to this fort were numerous. Among them were the following:—

1. That it is too strong. As one of my critics remarks:—"This design is fundamentally wrong in conception, since it does not take the British Navy into account." It was certainly intended to be as strong a fort as we are ever likely to want, perhaps more so than is actually required at Darland Hill, but it would have been made much stronger if it were not for the British Navy.

2. That no gun should be in the fort except, perhaps, in the flanks. This has been already discussed. This opinion is not universally held. I have seen a recent design for a fort with more guns in it than I should like to put there.

3. That, anyhow, the guns are too heavy. This point is certainly open to discussion. Heavy guns were chosen in order to overpower the enemy with superior weight of metal; but lighter ones would be more mobile, and would probably fire faster. The introduction of siege disappearing carriages would be in favour of the heavier guns.

4. That a considerable length of parapet, about one-fourth of the whole, is lost in the traverses necessitated by the heavy guns. The loss is true, but there is plenty left, and when the guns are taken out, which they would be at an early period of the siege, the musketry parapet could easily be extended. Besides, the traverses will help the infantry, and it is not clear why they should be refused this additional protection.

5. That the two tiers of fire are undesirable. This, again, is an opinion not universally held. In this case one tier fires on the glacis, the other on the ditch; one cannot hit the other. I should not introduce the second as a matter of course. The nature of the site affects the question. If the glacis were steep it would be necessary to bring the crest line near to the counterscarp, so that there would be no room for a double tier.

6. That the "tourelles" are untried and are weakly armed. Practical trials are, no doubt, necessary, but something of this nature is, I believe, required in the days of high angle shrapnel fire and high

explosives. It is admitted that some overhead cover must be devised for the men at the parapet. A great advantage to be derived from them is that they render possible a defence with small numbers of men.

7. That the ditch is weakly defended. This is based, first, on the opinion that the 6-pounder case shot is bad, which is a matter for experiment. If necessary a somewhat heavier gun must be used, such as the 8-pounder that was tried as a field gun. Secondly, that it would be difficult to man both parapets sufficiently in case of an assault. Some organization and drill would certainly be required to make full use of the garrison, but this is the case with most military operations.

8. That the "tourelles" should be either lower down, to be concealed, or higher up, to act on the glacis. They were put low down so as to be seen with difficulty, and the fire over the glacis was sacrificed to this. If they stand projectiles better than has been assumed, they might, with advantage, be put higher up. Experiments are wanted. Possibly we shall get our information from foreign sources, as these "tourelles" are to be largely used on the Continent.

Modified Design of Fort.—In *Plate* VII., I have endeavoured to embody the ideas of my critics as to the sort of fort they would prefer for Darland Hill. It will be understood that this is my interpretation of their views, and in no way binds any of them.

Keeping the counterscarp the same and the slope of the parapet at 1 in 7, the crest is thrown forward and the perimeter thereby increased. No guns are mounted on the front faces, so the width of the rampart is diminished.

Provision is made for field guns on the flanks of the work. Where the ground admits of it, it would be desirable to lower the parapet at which these guns are mounted, so as to give them additional cover against enfilade fire.

The traverses are omitted and the "tourelles" also. The parados and casemates are not re-designed. Their arrangements are not of primary importance and are susceptible of many variations. The observation stations have been retained, as some means must be provided for controlling the fire from the intermediate batteries. It should be noted that the ditch might have been made shallower without reducing the cover for the railing too much, but it has been left the same as in the other fort for more easy comparison.

This work is, of course, not intended to resist a regular siege. It is strong against other forms of attack except against fire from howit-

zers and mortars. Against this it depends on the accuracy of its own fire and the inaccuracy of that of the enemy. This I do not think is enough in important situations. It is too great a temptation to the enemy to increase his transport by that required for the necessary ammunition, and to endeavour to possess himself of some dockyard or coaling station by a bombardment and a rush. It should be made quite clear to him that this is impossible.

6.—CONTINUOUS LINES.

Continuous Lines.—It is occasionally desirable to construct continuous lines. It will, therefore, be useful to consider the details suitable to them, and the circumstances under which they should be employed.

A continuous line, if intended to resist an attack in form, must be organised as if it were the parapet of a large fort; the gun emplacements, banquettes, traverses, bomb-proofs, magazines, and communications must be similarly arranged, and the ditch defences constructed with equal care.

Organization of the Rampart.—The details of the organisation of the rampart will depend upon the curvature of the line and the consequent amount of its liability to enfilade and reverse fire; if this is great, parados and traverses must be freely used, and the best compromise that is possible under the circumstances made between the offence and defence; as there is more parapet space in a continuous line than a fort, there is not the same objection to cutting it up with numerous traverses.

If the curvature of the line be slight, the organisation will be simple, as parados will not be wanted, and only light traverses, as in the case of the front faces of a detached fort.

Ditch Defence.—The ditch defence of a continuous line will be similar to that of a detached fort. There are, however, two peculiarities to be borne in mind: one is, that owing to the necessary extent of parapet it will be possible for the defenders to develop such a fire of rifles and machine guns as to render it unnecessary to supplement it by quick-firing guns in "tourelles," unless it be of great importance to keep the numbers of the garrison at a minimum. The other is that the whole being, so to speak, a front face, a high counterscarp revetment can be used if special security be desired against assault, as the counterscarp will be secure against the enemy's fire.

It might in some cases be both practicable and economical of men to flank long sections of ditch with caponiers or counterscarp galleries.

Strengthening of a Particular Point.—If it be wished to strengthen any particular part of the line against a front attack, it may either be retrenched, or a lunette constructed in advance. The latter will be really a detached fort, but being closely supported should have only a light gorge, and need not contain many casemates.

Covered Way.—A continuous line should have a covered way; the communications with it should be numerous, and the entrances into the interior secure.

Entrances.—An entrance should be defended from some position quite separated from it, so that in the case of a surprise, or of an assault, the defence may be conducted coolly and undisturbed by retreating troops.

Strength to be Varied.—The strength of different parts of a continuous line should be proportioned to the nature of the attack they are likely to be called on to resist. The profile may vary, taking care, though, that the line is in all cases secure against assault for its whole length, or the advantage of using it is lost.

The Use of Continuous Lines.

When Continuous Lines should be used.—The rule appears to be this:—When it is necessary or very desirable to stop an enemy absolutely at a certain fixed line, a continuous line of fortification must be used; when this necessity does not exist, detached forts can be employed.

Continuous Lines for Enceintes.—Thus continuous lines are used for the enceintes of fortresses, because if this last line of defence be passed at any point, the enemy is actually in the very place that it is desired to guard.

Detached Forts for Outer Lines.—On the outer lines of defence detached works may be used, because if the enemy were to pass between them for a short distance he could do but little harm to the besieged, as he would not be near his objective, and if the place were properly laid out, should not be able to take up any good position. He would find himself between two fires with an opposing force in front; the lateral batteries in the forts he can neither silence nor take in a hurry; he would, therefore, have to retire and to make a

direct attack on one or two of the forts. Of course, if the latter were badly built and the garrison weak, their guns might be silenced at once and the field force crushed, and the obstacles to an attack on the inmost works thus removed; but a badly-built place, weakly garrisoned, must easily fall, whatever its design. When a place is in fair order an enemy cannot completely penetrate between the forts, and since a partial success in doing so would not much harm the besieged, so a continuous line is not necessary for the outer ring of works.

Continuous Lines for Plateaus.—The rule here laid down governs another case in which continuous lines have been used, that is, when they have been constructed along the edge of a plateau or the crest of a ridge. In these cases, unless the work were placed in this particular position, the front slopes of the hill could not be seen, and it is consequently necessary that the enemy should not pass it.

Continuous Lines in a Defile.—Continuous lines are also constructed across defiles and ridges at points where they are narrow. Here the reason for them is not quite the same. It is, of course, desirable to stop the enemy at a point where a few men can do it, and though this might be done by a fort in the middle of the defile, yet a continuous line in such a position is usually no more costly than a fort; it gives a larger front to oppose the enemy from, perhaps without a greater length of escarp; and the difficulty of securing the flanks satisfactorily is avoided.

Reasons against Continuous Lines.—The reasons against using continuous lines generally in the place of detached forts are the following:—

1. The increased cost necessary both to make them and to keep them up.

The truth of this clearly depends on the nature and distance apart of the detached forts, which again depends on the arms in use. When the range of firearms was less than it is now, continuous lines were more used. Although it has been said that continuous lines should be as cheap, or nearly so, as detached forts, yet, practically, they are not so under ordinary conditions. It may here, perhaps, be mentioned that I have made designs and estimates for over eleven miles of continuous line.

2. The careful guarding they require, as, unless they are well retrenched, passing them at any point may involve the loss of the whole.

3. The obstacle they present to the free movement of the defending troops.

Over some portions of ground these reasons may not apply; if it is very rugged, for instance, and the works would have to be very close, it may be advisable to run them together into one line. Here the enemy would not be likely to attack, and the ground would not be favourable for moving the defenders over it.

This case really comes under the original rule, that it is very desirable to stop the enemy on a certain line, and therefore a continuous line should be used.

Retrenchments to Continuous Lines.—Continuous lines should always be retrenched, so that their great defect, namely, their liability to be completely lost if pierced at any point, may be neutralised. In the case of lines close round a town, this precaution may be somewhat difficult to take; and, perhaps, there is less necessity for it than in the case of more extended works, for the garrison being crowded together, and being reduced to their last chance, the enemy is not likely to force an entrance at any point, except at the one which he may deliberately attack. The retrenchments would be of the nature of small forts; they need not see the ground outside the the lines, and should not be exposed to serious injury from the enemy's fire from thence. This last condition can usually be fulfilled only by giving them thick parapets, and by not allowing them to draw the enemy's fire by using their guns in the earlier part of the siege. On the other hand, they may sometimes be combined with the batteries for distant fire, but this is not desirable.

The best position for a retrenchment is on some spot in rear of the line, from which the latter can be seen, and at some little distance from it. Occasionally, a portion of the line forms part of the retrenchment, and in such a case this portion should be made exceptionally strong, so that the enemy may not be induced to attack it directly; salients, especially, require strengthening if used in this way.

Some lines of detached forts may be considered as the salients and retrenchments of a continuous line on a field trace, but not all; many modern works should be treated as the nuclei and important portions of groups of works which would be completed by field-works.

7.—LAND WORKS. TEMPORARY WORKS OF THE DEFENCE.

The Temporary Works of the Defence.—It is desirable to say a few words on the temporary works that have to be executed by the

garrison of a besieged place, and which play such a large part in the defence. They will be of the character of siege works, but may be more solidly constructed, as when once made they will seldom be abandoned for others, but will remain in use during the whole siege.

They will fall under two categories: first, those whose object it is to advance the defence beyond the existing line marked out by the forts; and, second, those intended to strengthen that or the advanced line. Brilliant results have often followed the first-mentioned application. It is, nevertheless, one that presupposes that the fortress was originally badly laid out, or that it has become more or less obsolete. It obviously means the construction of a new fortress either in whole or in part, in a more or less hurried manner, and, therefore, not so strongly as if built with deliberation. It can consequently only be used by a skilful commander provided with an adequate number of troops and stores. The main works will be of a provisional type and will be made as strong as circumstances will permit, as they will have to fulfil the functions of permanent works. The intermediate works will be the same as those required to fill in between permanent forts and will, in fact, be examples of those falling under the second category.

Various classes of Works.—The intermediate works will consist of redoubts, trenches, and batteries.

Redoubts.—The redoubts will have to be made with very solid parapets and numerous traverses, as they will not be retired from the front, but will be up in fighting line with the forts.

They may contain some light guns, but should not use them against the enemy's siege works if it can be helped, or they will draw his fire. They will be required at the last period of the siege. They should be dependent either on the forts or on works constructed in rear to support them. The enemy should not be able to gain a firm footing in the line of defence by capturing one of them.

They must contain bombproofs for the garrison, and some magazines, but the main magazine accommodation will either be in the forts or in the town.

Provisional Advanced Works.—The scale on which these works are laid out, and the nature of the design to which they are built, will depend on the time likely to be available for their completion, as well as on all the other conditions which affect the problem, such as the nature of the soil. In hasty works it is impossible to use the long slopes which are desirable in permanent forts, on account of the extensive movements of earth which they necessitate. Consequently such works will be much more liable to have their slopes injured and their communications blocked from the effects of shell fire. They will, in our service, be unable to make use of armoured protection for any of their guns, but in foreign works it is quite possible that this will not be the case, as there is no special difficulty in keeping turrets for the smaller natures of Q.F. guns in store and setting them up in a short time. The obstructions will be much the same as in permanent forts. The bombproofs can hardly be so good, but a great deal can be done with rails and concrete, particularly if the latter be made with a large proportion of cement.

The main redoubts and batteries for all fortresses should be designed during peace time, and all the necessary calculations made of the men, time and *matériel* required to construct them, the designs being revised periodically to ensure their being in accordance with the latest ideas. The work should, in addition, be laid out on the ground, profiles being set up for a short time, so that their exact position may be fixed and a setting-out plan prepared. This should be connected with well defined natural marks on the ground, such as trees or rocks, or, if necessary, with stones set in convenient positions. Bench marks should also be made to which the heights of the proposed work should be referred. If these precautions be taken, it would be possible to begin the earthwork of the redoubts a few hours after receiving the order to put the place in a state of defence. Even further preparations than these might be made by buying land, forming roads, building secure magazines and bombproofs, creating obstructions, and collecting stores near at hand.

Trenches.—The trenches will be partly communications, partly shooting lines; a few bombproofs might be constructed in the latter. The communications would, if possible, be the existing roads, sheltered from view by earthworks. This it is very desirable to do in peace time, if money can be spared for it. All new roads that may be constructed for the service of the works should be laid out so as to be covered from view as far as possible by the ground, and the possible necessity of still further protecting them at some future time should be kept in mind, so that they may not be placed, for instance, on the side of a steep hill sloping towards the enemy, where it would be impossible to make a covering parapet.

Batteries.—The batteries will be of a siege type, and will mount guns either on travelling carriages, traversing platforms, standing carriages, or HP. siege carriages, or will mount rifled howitzers or mortars, according to the amount of their exposure to fire, and the

work they have to do. The batteries containing the guns for firing on the enemy's first artillery position may be almost or altogether hidden from view by being placed on the rear slopes of hills, the fire being directed by reverse laying, to carry out which some well-marked object at a distance from the guns must be visible from them; but, as a rule, the batteries of the defence will be less able to take advantage of this mode of protection than those of the attack, because their objects are not equally well defined, and are more subject to variation.

Occasionally the guns might be blinded with advantage; if, for instance, they were mounted in the interior of a fort to give curved fire, since in this position they would be liable to injury from shrapnel and such projectiles as would be fired at the fort; but this is an improbable position for them, except in an isolated work.

Alternative emplacements should be made for important guns, and for those whose position is by any means liable to be detected. These positions need not be very distant from the original ones, but just enough to throw out the enemy's aim.

Guns on Railway Trucks.—It is probable that in future the maximum of mobility for the heavier guns and howitzers of the defence will be attained by mounting them in such a manner that they can be fired off special railway trucks. It would be then possible to move them right or left at very short notice. If they can be carried on the trucks on their own carriages, they can also be moved out to any advantageous positions where the lines are not, or, perhaps, cannot, be laid. The whole of the ground of the defence would then be available for batteries. This is the most generally advantageous arrangement, if it can be carried out without going to inconvenient dimensions, either for the trucks or for the covering parapet.

The gun can be designed to be fired off the truck, either approximately in the line of the rails or approximately at right angles to them. In both cases, firing can only take place where the rails have been specially prepared for it. In the first method, the gun must, therefore, be brought up to a definite point for firing, which is objectionable, and the only advantage gained by the use of rails is that it can be moved more easily from one of these points to another than if it were on its own wheels.

In the second method, the line can be carried in rear of a parapet, and lengths of it can be prepared for firing. The guns can, therefore, be shifted a short distance if the fire be severe or the parapet injured, or they can be massed together, or moved to a distant spot. This is evidently the best arrangement.

It is to be observed that advantage would be gained by the use even of a short isolated bit of line, if the ground will not admit of more, although, of course, freedom of movement is increased by having the railway continuous.

It is possible that our fortresses will, eventually, be provided in the intervals between the forts with railway lines behind parapets, over which the guns will fire. These lines should be additional to any railway intended for purposes of supply or transport of troops, although it would be desirable that the two systems should be connected.

It will seldom be possible to construct many of the batteries of the defence beforehand, as their positions and objects depend on the nature of the attack, and, moreover, it is most undesirable to allow their positions to be known. Nevertheless, by a careful inspection of the country round a fortress, the most advantageous sites for the works of an attack may be discovered and noted, and if batteries be thrown up to command these points as a preparation for putting the place in a state of defence, it is pretty certain that the labour will not be thrown away.

Position of the Temporary Works.—The question may be now asked whether the supplementary works should be in line with the permanent forts, or behind, or before them.

Looking to the fact that one object of constructing these works is to prevent the enemy's fire from being directed exclusively on the forts, it appears advisable in the beginning of a siege to build some of them in advance, if the ground admits of it.

This position has also the great advantage of either forcing the enemy to begin his approaches at a greater distance than he would otherwise do, or of enabling a heavier fire to be directed on him, if the character of the ground be such as to fix the point at which he will open his trenches.

Next comes the point of deciding at what distance from the forts these works should be placed.

This may be best settled by a consideration of the advantages gained by permanently fortifying a place, as these advantages should of course, if possible, be retained, or otherwise the enemy may be met on inferior terms. They are: a powerful artillery, secure magazines, safe bombproof accommodation, and security from assault.

The magazines and bombproofs are in the forts, and the temporary works should not be far from them. The forts should be secure from assault, and the advanced works will be well guarded if they are seen into at a short range. Any permanent arrangements for mounting artillery will be in or behind the line of the forts.

This distance should be such as to enable the heavy guns of the permanent works to fire with effect over the advanced works, and to permit of the easy bringing up of men, ammunition, and guns, and of withdrawing them, if necessary; the batteries should also be within close musketry range, and thus be well supported.

For these reasons it may be concluded that some of the temporary works may be in advance, but should not, as a rule, be more than about 500 yards from the line of the forts.

It must be remembered that the pickets will be in advance of these batteries, and that thus a strip of about half-a-mile wide may be added to the area of the fortress, which will be so much more for the garrison to defend.

As the attack progresses, the guns and men may be withdrawn from the advanced batteries to others, which will, in the meantime, have been constructed further back, either between the forts or in rear of them, according to the ground, for the forts themselves must bear the brunt of the attack in its last stages. The first batteries, however, will by that time have done their work, in causing delay to the enemy. Care must be taken that their remains do not assist the enemy's trenches.

The position for the temporary works just arrived at is, of course, subject to modification, according to the nature of the ground; indeed, this is, in practice, the principal factor in the determination of the problem, and the distance named of 500 yards will seldom hold good except in very open and level country.

The reasons for adopting it should, however, always be kept in mind, and the temptation to go to the splendid position which, somehow, always seems to exist in front of a line of works, should be sternly resisted. If yielded to, it is likely to lead one into building another line of forts in front of these already existing, which is hardly the way to make the best use of the latter.

There is a case though in which this limit may be exceeded; it is when, from the broken nature of the country, it is impossible to place the forts so that they shall command the ground at all nearly up to the limit of the effective range of their guns. In this case it may be possible, by constructing works on a ridge in advance, to force the enemy to open his trenches at a much greater distance than he would otherwise do. There must, however, be a strong garrison to venture on doing this, and, properly, such a case should have been met beforehand, by the construction of permanent works on the ridge in advance of that actually occupied, as well as on the latter.

Expense may, however, be prohibitive of this, and, of course, even a single line of works should secure the place against assault.

8.—CHARACTER OF WORKS AS AFFECTED BY THE CONTOUR OF THE GROUND.

The principal forts round a place are those which hold positions whose occupation by an enemy would be of special importance, either because they command other works, or because their capture would open an easy road for a further advance. In these cases the defence of the near ground requires the most careful consideration, in order that the enemy may be forced to attack in form and go through all the operations of a siege, and, consequently, as there must be no dead ground near to facilitate the construction of approaches, the form of the work is very dependent on the contours of the surface.

Level Ground.—On level, or on gently undulating ground, this requirement is least exacting, and the work then should be of a fair size, proportioned to the importance of the fortress, and should, if possible, not have any special saliency on the side on which the final approaches are most likely to be made.

Steep Ground.—When, however, the slopes of the ground are steep, the design must conform more to local conditions, and less to any preconceived theory.

The various cases of steeply sloping ground may be classed as follows:—

1. A single peak.
2. A straight ridge perpendicular to the general lines of the defences.
3. A peak with radiating ridges and valleys.
4. A rounded hill.
5. A plateau with steep sides.

1. *A Peak.*—In the first case, the work occupying the peak may be absolutely limited in size and in outline, and it may be impossible to find room for many guns, or to alter the positions of those which may be mounted by modifying the parapet in any way

during the course of a siege, and it may also be impossible to oppose a broad front to the last stages of the attack; great attention must, therefore, be paid to the mounting of the guns and to the details of the defences of the ditch. If the peak be of rock, as is most usual, high escarps can be formed in it without danger of their being breached easily. The things to avoid in such a work are using steep slopes and forming shell traps.

A work in such a situation will probably differ considerably from the examples given in preceding sections. With a good escarp and secure bombproofs, it may be counted on to hold its own. If it be intended to operate powerfully on the surrounding country, it may be necessary to put some of the guns in cupolas, but the use of siege disappearing carriages, and of howitzers that can be fired from concealed situations, will probably be sufficient.

2. *A Ridge.*—To prevent the advance of an enemy along a ridge, a good big ditch is the best obstacle. If possible the fort should be placed at some point where the ridge widens out, so that it may have a longer front than its assailant in the last period of the attack. If it can be made in the form of a horn work, with the flanks thrown forward, and the centre of the face retired, it will be rendered strong against a front attack, but, of course, it must not be possible to operate against the flanks.

A ridge may be held by a fort with lines on either flank dependent on it.

On a ridge, two or three lines of works can often be constructed, those behind firing over those in front. In such a case the functions of each may be different; the front lines may be organized entirely to repel the close attack, while those in rear may mount guns for distant fire, and may sometimes become merely a group of gun emplacements.

3. *A Peak with Radiating Ridges.*—The defence of a peak with ridges radiating from it, requires a group of works, namely, a central work on the peak, with outlying ones on the ridges, their relative strength varying according to their distance apart, and the character of the attack to which they are liable.

Sometimes the central work may be in all respects the chief, and the outlying ones become mere advanced lunettes, perhaps even built on a field trace. This is the case when the central work can be made large and powerful, and when it sees nearly all the ground in front, in fact, when the radiating ridges are not very strongly marked.

At other times one or two of the outlying works may be so much exposed to attack, and may have such a command over the field of an enemy's approach, that they may require the principal amount of attention, and the central work may dwindle down to a small post on the highest ground, intended to prevent the enemy capturing by surprise a dominating position.

There are many fortified positions which really fall into this class, though they do not appear to at first sight; they are those in which either the central point or one of the ridges is of decidedly superior importance to all the others, and is fortified in consequence, while the others are left untouched, to be occupied by field works in war time.

In designing a work for ground of this character, the requirements of these future additions should not be overlooked, and the fort should be provided with accommodation for the men, ammunition, and guns necessary for them.

Sometimes it is possible to develop the glacis and covered way of the main work, so as to include one or more of the subordinate positions; this has been done in some of the works at Malta.

When a covered way is made of such importance as this, its parapet will require organizing for defence almost as carefully as that of the main work.

When a group of works is constructed in a fortress, it becomes of necessity a small fortress in itself, and it may be convenient to treat it as the citadel of the whole place.

4. *A Rounded Hill.*—A rounded hill of a size too large to be included in one work, and of which the sides for some distance get steeper as they descend, is about the most difficult ground there is to occupy.

It can only be done in one of three ways; either by cutting it away, so that the sides may be seen from a work on the top, which is a method likely to be costly in land and labour; or by building outworks along the top of the steepest slope, which is what must usually be done, though the communications will be exposed, and the works very prominent from the high relief necessarily given to them; or by occupying the top of the hill only, and defending the steep slopes by the fire of collateral works.

5. *A Steep-Sided Plateau.*—The edge of a steep-sided plateau is the part of it that must of necessity be held, and it depends on the exact conformation of the ground in any particular case, whether it is best to do this by means of separate works on the salients or by

a continuous line. Dueira Lines, in Malta, is an instance of a case where it was necessary to adopt the latter alternative.

2.—DISPOSITION OF WORKS UNDER VARIOUS CIRCUMSTANCES.

The manner in which the works should be disposed is the first question to decide on in connection with the defence of any particular place. The number and variety of the conditions bearing on this problem render it impossible to lay down any general rule for its solution, but an examination of several particular cases will at any rate be suggestive as to some ways of approaching it.

Typical Modern Fortress.—The typical modern fortress may be defined as a town, dockyard, or arsenal, surrounded by a prepared fighting position, having the points of main tactical importance occupied by detached forts, and the artillery disposed in a ring of batteries protected by them.

This differs materially from the definition written a few years ago which described a fortress as having an interior enceinte and an outer ring of detached forts. The difference has been brought about by the improvements in weapons, which have driven the guns out of the forts. The batteries for these guns, with their communications and the various redoubts and trenches thrown up by the Field Force, will to a great extent supersede the enceinte, by increasing the difficulty of penetrating the intervals between the forts, and at the same time rendering it more necessary to prevent the enemy doing so.

It will be noticed that this definition brings fortification almost into line with ordinary field tactics. There is no longer any essential difference between them. The details of fortification, with the minutiæ of bastions and ravelins, fausse-braies and caponiers, no longer govern the disposition of the troops. Instead, the troops occupy a certain position; this is strengthened by providing certain important points with cover and obstacles against assault, and by constructing batteries for the artillery. The number of men required can thus be reduced, while at the same time the security of the place is increased. The basis of the whole and the main object for consideration is the Field Force.

It must not be imagined from this that the functions of the Engineer are of lessened importance. It is the increased complexity of the problems he has to solve that has brought about this change, and made it less possible to give rules to assist him in solving them. The works must be placed with more thorough adaptation to the features of the ground, the casemates must be secured against more powerful projectiles than of old, and the arrangement of the obstacles must be such as to utilize the fire of more efficient weapons.

There are many modifications of the typical plan, and by mentioning these we may arrive at some conclusions as to the nature of the works which should be constructed in different cases.

The Detached Forts.—The detached forts round a place may be disposed in one of two ways; either they may be numerous and designed to see every fold of the ground, or they may be fewer in number, placed on points where they cannot be neglected by the enemy, and the defence of the ground in its details completed by field works supported by the forts.

The first method prevailed when detached forts first came into general use, and when it was thought that a line might be defended from the forts alone, as it had been from the continuous works of earlier days. The latter is, however, the one that should now be followed; it enables the forts to be made large and strong, it reduces the number of vital points, and by not forcing the design to be too much influenced by the accidents of the ground, gives greater freedom of choice for the sites of the works.

Even if, as is sometimes the case, the ground is unsuited for the employment of field works, and numerous permanent works must be built, the spirit of this latter method should be kept in mind, and the defences should be grouped and not form a mere line of scattered units.

Distance apart of the Detached Forts.—The distance apart of the forts depends on the ground and the nature of the defending and attacking troops, and may vary from 500 yards to 5 miles, or more.

The former might be the distance, either in the case of some very uneven ground which it was, nevertheless, necessary to defend in detail, or to the smallness of the garrison, or to the nearness of the works to the place to be defended.

The latter might be the distance, either in the case of there being very few lines of approach to a fortress, or in the case of the fortress being of great importance and very large size, and, therefore, with a numerous garrison; then, key positions only need be permanently fortified, the necessary filling in being easily done with field works.

The ordinary distance apart would naturally be something between

these, something between 1,500 and 4,000 yards probably; 1,500 yards enables the ground between to be well commanded by small arm fire; 4,000 yards may be considered the limit at which works would afford one another mutual support by artillery; but each case must be decided on its merits.

Choice of Sites for Forts.—In the choice of sites for forts the main advanced works should occupy good tactical positions, commanding the enemy's best line of approach to the town defended. He will then be forced to make regular siege works against them, as it will be impossible to ignore them.

Some of the forts may be constructed mainly to deliver either direct or flanking fire, but these are subsidiary to the above mentioned works. In those cases in which they are used their employment is dictated by the form of the ground.

When the good lines of approach to a fortress are few, only a few permanent works need be made, but an inner line of some kind is then a necessity.

Ring of Forts sometimes not Suitable.—Occasionally a ring of forts is not suitable to the ground, which may be best taken up by groups of works commanding the approaches; these should be kept as compact as possible, as their garrisons will be isolated and unable to aid one another.

Enceinte.—In some cases an enceinte is required in addition to the forts, and it exists in many fortresses. It may be of different degrees of strength, varying from a line of the most powerful construction, such as the enceinte of Antwerp, intended to resist all the efforts of a besieger to the very last, down to nothing.

If it be impossible to follow the typical plan and to place the guns between the forts, an enceinte should be constructed, making it on a field trace if it is not part of the permanent works of the fortress. Its existence will render it easier to hold the outer line, and will diminish the number of the garrison required to be formed into a field force, since it will be no longer of any use for the enemy to attempt to push a body of men between the forts on the chance of taking the place by a *coup de main*, as one or two of the forts must be captured in order to establish batteries against the enceinte.

The nature, therefore, of the enceinte required for any particular place will depend on such considerations as the following:—

If the place is of such importance that it is necessary to hold it for the very longest time possible, then an enceinte must be built as if it had to stand alone.

In any other case it does not appear advisable to expend very much upon it, but instead to strengthen the outer line, for a weak enceinte is sufficient for most purposes, until a formal attack can be made upon it, and it can be improvised by the labour of the civil population while the siege is going on.

If the garrison is likely to be small it is especially desirable to have an enceinte.

If from the nature of the ground, or of the buildings of the town, there is likely to be a difficulty in improvising an enceinte, something might be done towards constructing it in a permanent form without executing the whole. The salients might be built, or some small detached forts made in places where they would support a future line of field works.

A Citadel.—If there be one dominating point near the town, and a strong citadel be constructed on it, considerable support will be afforded to any improvised enceinte.

Inner Line of Detached Forts.—An inner line of detached works sometimes takes the place of the enceinte, when old fortresses have been enlarged. It would be advisable to connect them by field-works.

Town with Few Lines of Approach.—It sometimes happens that there are only a very few lines of approach to a town that can be made use of by an army, and that these are blocked by detached forts. It is then particularly necessary that the town should be provided with an enceinte to keep off the smaller bodies of men that could pass over the ground between the intervals of the forts.

This is a case that varies so much from the typical form as to require different treatment altogether.

Distance between Detached Forts and Enceinte.—The distance which should separate the detached forts from an enceinte cannot be exactly laid down, although it is no doubt desirable that they should command all the ground between them. The observance of this condition would limit the distance to about 5,000 yards, and would also demand open ground, which can rarely be got.

There are other conditions of greater practical importance to be fulfilled. The detached forts must be sufficiently far in advance to prevent a bombardment, and they should be on ground favourable for their action to the front. The enceinte, too, must be on favourable ground, and not too much extended.

As a consequence the forts can often see but a short way to their rear, and are commonly at a long distance from the enceinte.

Therefore, since all the ground cannot be commanded, as much should be as possible; how this can be done must depend on the ground. It may be necessary to construct works in rear of the advanced line and supporting it. This resource should be very sparingly used, as these works will absorb a part of the garrison, and may, perhaps, never affect the result of the siege.

Small Fortified Places.—The greatest variations from approved theory, of course occur, in small fortified places, such as those designed to protect our minor coaling stations.

As it would not be right to spend much money on these places, or to lock up large garrisons in them, they cannot be given a theoretical completeness; on the other hand they must not be expected to hold out for long without being relieved.

The normal arrangement for a small place of this kind may, perhaps, be taken to be a citadel with a ring of detached works, at about 3,000 to 4,000 yards, or even less, from the town. This ring would give considerable protection against bombardment, as the enemy would be compelled to fire at ranges which require very accurate shooting, while, the perimeter being less, the garrison will be much smaller than for a first-class place. The citadel will enable what remains of the garrison to hold out for some time after the other works may have fallen, and should be so situated as to prevent the enemy using the place for his purposes; therefore, in the case of the defence of a coaling station, it is desirable that the citadel should command the harbour with some heavy guns or howitzers.

In these small fortresses it is never probable that there will be numerous garrisons, and, therefore, the works should be arranged with especial attention to the command of the ground near them, and they should be constructed so that the garrisons may be secure from assault.

There are many varieties of form in small fortresses; among them are a ring of forts without an enceinte, and an enceinte without a ring of forts; a ring of forts with one or two far outlying forts; isolated posts defending the roads of approach, and a fortified camp near the place to be defended; the last arrangement is only to be recommended when the ground around the place is very unfavourable for defence.

The choice between the varieties depends mainly on the form of the ground, which has even more influence on the design of a small place than on that of a large one.

10.—CALCULATION OF GARRISONS.

It is necessary to calculate the garrisons of works when designing them, in order to be able to arrange for the proper amount of accommodation and storage, and also, if the number of men available be limited, to see that the works are not projected on such an extensive scale as absolutely to require larger garrisons than can be allotted to them.

Garrison for a Single Fort.—The calculation for a single work is made as follows :—

Take the number of men required to work the maximum number of guns in the fort that can be in action at once, and the guards required for the entrances, for the parapet, for the flanks or caponiers, and for the covered way, if any, and multiply by three for reliefs. To these add cooks and cooks' mates, storekeepers, permanent magazine men, orderlies, telegraphists, officers' servants, and officers. The sum of these gives the full garrison required for a fort exposed to a regular siege. A fort not liable to an attack of long duration need not have three reliefs for its gun detachments.

Numbers required to man the Parapet.—No special addition is necessary for manning the parapet, unless the work is unusually large, or unless it be a continuous line. In the latter case Sir John Jones's formula, as applied to the Lines of Torres Verdras, may be taken as a guide. It was, "two men per yard running for all front lines, and one man per yard for all rear lines, deducting for the spaces occupied by the artillery ; an addition to, or deduction from these numbers being made by the commanding engineer in all cases, where deemed expedient from local causes." This gave enough men to man the parapet thoroughly, and to have a reserve to replace casualties and to strengthen the defence when needed.

This calculation was for strongly made field works. For permanent works and with modern weapons one man per yard would probably be enough in all cases, with the addition or deduction made as suggested by Sir John Jones.

Whole Garrison not to be always in a Fort.—It does not follow that the number of men calculated as required for a fort should always be in it. There should be a permanent garrison for the work, who should always be there, who would know the way about, and take charge of the stores, but the reliefs for working the guns had much better be out of the fort when they are not actually wanted, and with a fort which is one of a line, this can be arranged. In isolated works, of course, the full garrison must be kept.

Number of Men for a Gun.—In calculating a garrison, reference can be made to the Manual of Artillery Exercises for the number of men required for the various natures of guns that may be mounted. For a medium gun such as the 64-pr. R.M.L., or for a field gun, the detachment consists of nine men, of whom two are magazine men, who may not be required for every gun in a work.

Field Force.—In addition to the garrisons of the forts, a Field Force is required for many duties ; firstly, to watch, and secondly, to guard the intervals between the forts ; thirdly, to make sorties, and fourthly, counter-approaches. It would also, fifthly, strengthen its position by throwing up field redoubts and shelter trenches, and would, sixthly, work some of the guns of the batteries intermediate to the forts in which the artillery of the defence would be mainly placed during the second period of the siege. While the guns of the forts were silent, part of their garrisons would be available for use outside them, and they would be told off to some of the intermediate batteries, the remainder being worked by men of the field force.

Calculation of the Field Force.—Guards and Pickets.—The Field Force is calculated, firstly, by allowing sufficient men to form a ring of guards and pickets all round the fortress. This can only be done accurately on the actual ground, but for a uniform site, 33 men would be required for every 100 yards in order to provide main guards, with pickets at 300 yards intervals, and with double sentries detached to the front. In a coast fortress, guards and pickets will be required to watch the shore and the landing places.

Moveable Force.—Secondly, by adding a sufficient force to resist any attempt of the enemy to penetrate between the forts ; and in a coast fortress to resist a landing.

The amount of the necessary force will depend on a variety of circumstances, and it can be arrived at only by answering in each particular case, the question : "What has the enemy to get by penetrating between the works, and with what force might he try to do it?"

Chance of an Open Attack against a Fortress in Good Condition.—Against a carefully designed fortress in good repair, with an interior enceinte enclosing the vital parts, and outlying forts occupying all the important positions, nothing could be done by an attempt at an operation of this description ; without the possibility of taking up any good tactical position, and almost always exposed to fire from works which cannot be captured, the attacking force would be able to achieve nothing decisive, and must suffer great loss.

Small Field Force then only required.—In this case, therefore, no addition need be made to the pickets to enable them to resist a powerful attack, though there must be some troops to keep off small bodies of the enemy, who might try to slip in and do mischief.

Possibly the pickets and main guards will be enough for this; at any rate, troops will have to be added for other purposes who could undertake this duty.

It may be said that the forts might be so knocked about in the course of a siege, as to be no longer capable of opposing the enemy's advance; this, however, is not likely to be the case. They should be so built that to injure them seriously, it should be necessary for the enemy to establish regular breaching and counter-batteries, and it will be a sufficiently extensive operation for him to do this on the principal front of attack. But when the attack had been once localised in this manner, defences against it can be increased by mounting guns and constructing field works, and by bringing men from other parts of the fortress, so that an attack in force should become a desperate undertaking. The forts might have their artillery silenced, but their musketry can never be quite subdued, and they still hold the principal points of the position, needing to be carried by storm before the enemy can make good his footing.

Open Attack against an Imperfect Fortress.—The case in which the enemy is most likely to make an attempt to penetrate between the forts is when the ground is such that it can be easily moved over; when the forts are far apart, without much flanking fire, and so situated that they command the ground in rear for a short distance only; and when there is no interior enceinte, supporting work, or citadel. In such a case the forts have become merely batteries that cannot be easily silenced or taken, but they can have very little influence on the general defence, and the ground would have to be occupied nearly as strongly as if it were an open battle-field; a carefully prepared one, no doubt, and one in which the defenders have the advantage of powerful artillery, and cannot be outflanked, but still, in reality, nothing but an open battle-field.

Large Field Force then required.—It would probably be necessary in this case to allow three men per yard over the whole portion that can be attacked at once, which might be, say, half the fortress. The total number of men that this would necessitate, would, of course, depend on the possible extent of the attack, and on the facilities that might exist for moving the reserves from one part to another.

It will probably be thought that a place which requires to be

defended by an army can hardly be called a fortress at all. The description just given, however, applied fairly to some of the German fortresses, as reconstructed after 1871, except that they usually have a nucleus of old works, and stand in open country. The Germans, however, can start with the assumption that there are plenty of troops available, and consequently have probably not troubled much to do away with the necessity for using them. They have only had to make the positions strong against a frontal attack, in which they have, no doubt, succeeded. It is far otherwise with us, and we must not copy their example, but endeavour to make our works serve the place of men as far as is possible.

It is evident that the proportion of the field force required to guard the intervals between the forts, cannot be laid down in a general manner applicable to all fortresses; it must be determined specially for each case; and the determination requires a good knowledge of the ground, and of the capabilities of the works of defence. The importance of a careful preparation of the design of the works is, however, impressed on one by the consideration that according as they are well or ill arranged, there may be made a difference of perhaps 25,000 men in the garrison necessary for the security of a large inland fortress.

Sorties.—But a field force is also required to make sorties, and sometimes to construct counter-approaches against the enemy. It is not possible to base any calculation as to numbers on these requirements, but the necessity of having men available for them, especially for the sorties, furnishes another reason for providing a force additional to the pickets.

For the sorties, a small body of cavalry and of horse artillery is required.

Numbers necessary for throwing up Intermediate Works.—The number necessary for throwing up works intermediate to the forts is also difficult to calculate.

Probably an assumption sufficiently near the truth would be to take it at two men per yard over the front liable to be attacked; that is, in most cases, the front covered by three forts. This number is arrived at through the following considerations.

1st. That a man per yard on an average, would give a sufficiently large number for one relief on the various works required. Some of the work would be batteries requiring more than a man a yard to execute them; some trenches requiring about that number, some shelter trenches not requiring so much, but that would seem to give a fair average; a little over the mark, if anything.

2nd. That men enough for two reliefs per day will be sufficient, as most of the work will be done once for all, and continuous labour will not be required, as in the case of the besieging troops.

This number may be taken as a maximum, and as only necessary when a siege is expected, or at its commencement. In the former case civilian labour can be utilized, and a material reduction made in the garrison.

For the construction of works in a second line, the assistance of the civilian population of the place can be counted on.

Number of Men required to work the Guns in the Intermediate Batteries.—For the sixth requirement, men to work the guns, and to guard the batteries intermediate to the forts, as well as to guard any redoubts that may have been thrown up, the calculation depends on the number of guns to be used, and on the character of the works, which again depends on local circumstances.

It would, however, seem a fair assumption to allow a man per yard to the fronts liable to be attacked, which, added to the working parties just calculated, will bring up the number to three men per yard for the fronts liable to be attacked. The men for these duties may be fairly called on to do the sorties and counter-approaches, as they will not otherwise be constantly required.

Amount of Moveable Force.—This number is that which, as we have seen before, it is necessary to allow for the fronts of an imperfect fortress, liable to an open attack.

We have, therefore, arrived at this conclusion, that in addition to the garrisons of the forts and to the pickets, a force calculated at the rate of three men per yard is required for the whole number of fronts that may be liable to a simultaneous attack, *whatever the nature of that attack may be*, whether an open one, or carried on by siege works. This number is a maximum, and can be reduced by building well arranged works, and providing sufficient stores in time of peace.

Orderlies.—The Sick.—An addition must be made to the numbers of any force thus found to be requisite to allow for orderlies and men on such duties, and for the sick.

Additions to be made for the above.—For the besieging force this addition would be taken at $\frac{2}{10}$ths of the whole; for the besieged we might reduce it to $\frac{1}{10}$th; for they will be stationary, and will be

able to avail themselves of the services of the civil population of the fortress for many things which the besiegers will have to do for themselves.

Summary of Calculations for a Garrison.—To sum up shortly the calculations for the garrison of a large fortress we have:—

For the Forts.—To take the number of men required for guards and for working the guns, and to multiply it by three; to this to add the numbers required for miscellaneous duties, and where there is an unusual extent of musketry parapet to be manned, to allow for it at about the rate of a man per yard.

For the Field Force.—To allow for pickets at the rate of 33 men per 100 yards of outpost lines all round the place; for the main body, at the rate of three men per yard over the fronts liable to be attacked, either openly or with siege works, as a maximum. To these to add a small proportion of cavalry and field artillery dependent on the nature of the country and on the possibilities of making sorties, and to the whole field force to add $\frac{1}{10}$th, that is $\frac{1}{9}$th of the number just arrived at, to allow for sick and for men on various miscellaneous duties. This calculation will be found to give about 125 men per 100 yards of circumference of the fortress, which is reducible to about 75 men per 100 yards if the place is well prepared.

Case of a Full Garrison not being obtainable.—In the foregoing pages I have endeavoured to arrive at a mode of calculating the garrison of a fortress, according to what appears to be its real requirements; but in the English service it is very doubtful if a full garrison for a fortress could ever be obtained, and, therefore, the consideration of what men we can do without is an important part of our enquiries.

Change of Duties.—Economy of men must be obtained by shifting them about from one duty to another according to the exigencies of the situation.

Before the Investment.—Before the place is invested small numbers only need be kept in the forts; all the remainder, with the exception of some guards and pickets, being employed in clearing the ground to the front, and in constructing trenches and field redoubts where they may be required in the intervals between the permanent works. At this period, civilian labour should be employed. The men in the forts should prepare them for the siege by constructing blindages and covered communications, and, perhaps, by mounting guns in them; for at the beginning of a siege the forts should be able to speak decidedly; later on these guns would be taken out of them.

After the Investment.—When the place is invested, all the forts should be pretty strongly garrisoned, as they constitute the mainstay of the defence at this period. The pickets and sentries would be all posted. The remainder of the troops, forming the field force, would probably be kept in hand in such positions as would give them freedom of movement towards any threatened point.

During a Regular Attack.—As the attack develops, the garrisons of the forts and batteries against which it is more particularly directed must be reinforced up to their full strength, if it be possible, as the men will have plenty of work to do, while the number of reliefs for the remaining works can be reduced. The field force will now throw up counter-batteries, and some of the guns of the forts will be removed to them. So that, first, the working parties must be at their greatest strength; afterwards, the garrisons of the forts generally; and, finally, the troops employed about the point of attack.

11.—DETERMINATION OF THE ARMAMENT OF A FORTRESS.

It is impossible to lay down general rules for this determination, which depends for its solution on so many varying elements, such as the nature of the works, the configuration of the ground, and the numbers of the garrisons. It must, nevertheless, be made in all cases, and a few observations on the subject may give assistance.

In the first place the armament of each fort should be sufficient and suited in character to the work it has to do; that is, in most cases, to oppose the first efforts of a besieger, to protect itself against the last stages of an attack, and to help in closing the intervals between the works. The description of the forts in this chapter will be of some guidance in deciding on this.

The armament of the works permanently built for direct fire would be settled by the form of the ground.

The number of field guns to be used in sorties would depend on the strength of that part of the garrison likely to be available for such purposes.

It remains to be decided how many guns should be added to those determined on as above, for arming intermediate batteries. This must be done for each fortress separately. The object which it would be desirable to obtain, would be to establish a superiority of fire over the besieger. This can rarely be done, but it might be possible in cases where the ground on which he could establish his

batteries, was, from any cause, much limited in area, while that of the defence was more extended.

In ordinary cases it will be sufficient to provide artillery to arm all the batteries that could be constructed in favourable positions, allowing for the guns that will be removed from the forts for this purpose.

As any guns permanently mounted in the forts would be of the heavier class of medium guns, the deficiency is likely to be in the class of light guns and rifled howitzers, and attention should be given to this point.

It will be found that by satisfying the requirements of the works, the garrison will be provided with more than the proportion of three guns per 1,000 men, which is usually considered the normal amount for an army in the field.

Permanent Fortification For English Engineers

LEWIS

Chapter 2

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CHAPTER II.

DETAILS OF PERMANENT FORTIFICATIONS COMMON TO LAND AND COAST WORKS.

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1. Modes of Mounting Guns—Medium and Light Guns; Rifled Howitzers; S.B. Guns and Mortars; Q.F. Guns; Machine Guns; Rifles.—2. Mines.—3. Accommodation for Garrisons.—4. Passages and Communications.—5. Escarps and Counterscarps.—6. Fences.—7. Gates and Keys.—8. Caponiers and Flanking Galleries.—9. Drawbridges.—10. Effect of Nature of Soil on Design.—11. Hints on Design.—12. Preparations against Attack.

1.—MODES OF MOUNTING GUNS.

The modes of mounting the various natures of guns and howitzers on land works are rather numerous, as they have in late years been increased by several new patterns of carriages and slides.

Their nature, and the emplacement needed for each, will be shortly described, beginning with the medium guns, a convenient but somewhat inaccurate term, including the R.M.L. rifled guns, weighing from about three tons up to five tons, such as the 64-pounders and 80-pounders R.M.L., and 7-in. R.B.L., and then going on to the B.L. guns, the rifled howitzers, and the smaller weapons.

Garrison Standing Carriage.—Possibly there are some guns still mounted on carriages of this nature. It might be used for mounting guns not intended to be placed on the front faces of a fort, but to be employed for curved fire.

This carriage requires a ground platform of wood, stone, or concrete, 18 feet by 12 feet, and with a slope of $\frac{1}{24}$. The gun mounted on it will fire over a sill two feet three inches high.

64-pounder R.M.L. guns are not to be mounted on garrison standing but on rear chock carriages, on account of the recoil. Their platform should have a slope of $4\frac{1}{2}°$, or 1 in 12·7, and should not be less than 13 feet long.

Slide, 16-foot.—A wooden slide, 16 feet long, with sliding carriage, is the ordinary mounting for medium rifled guns, and is used in a variety of positions on land and coast works, both on flanks and faces.

The slide may be either "casemate" or "dwarf," according to the size of the trucks attached to it.

If "casemate," the gun will fire over a height of sill of 2 feet 7 inches, and the mounting is suited for use in casemates or Haxos. It is often superseded in these positions by the two patterns of shortened slide, which are described further on.

If "dwarf," the gun will fire over a height of sill of 4 feet 3 inches. The mounting is thus suited for a gun in a barbette emplacement, or firing through an embrasure.

This barbette mounting used to be the best for guns, particularly for those in coast batteries, and it is still fairly efficient for the latter, at least in positions not exposed to a close attack, but it should no longer be used for land works at all. It is, however, necessary to describe its emplacements here, in order to understand its modifications and the new designs based on it.

Racers for 16-foot Slides.—The radii of the racers for these slides, with their distinguishing letters, are given below. See also the diagram which follows :—

Letter.	Radii of Racers. Front. ft. in.	Radii of Racers. Rear. ft. in.
A	5 0	16 6
B	1 10	12 10
C	6 1	
D	9 0	3 $4\frac{1}{2}$
E	10 $8\frac{1}{4}$	2 2
F	12 10	2 2

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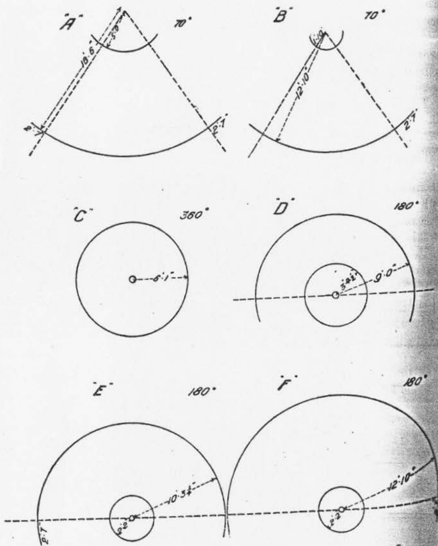
Letter.	Front.	Rear.
	ft. in.	ft. in.
A	5 0	16 6
B	1 10	12 10
C	6 1	6 1
D	9 0	3 $4\frac{1}{2}$
E	10 $8\frac{1}{4}$	2 2
F	12 10	2 2

DIAGRAM OF RACERS FOR MEDIUM GUNS.



Casemate slides are not used with other than A pivot racers.

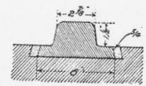
Dwarf slides can be suited to all, but B pivots are not much used now, and E and F pivots are specially adapted for the tops of Martello towers, and are not laid elsewhere.

A pivot racers are suitable with embrasures; C pivot for barbette emplacements with less than 140° of lateral training; D pivot for barbettes with a larger amount.

C pivot emplacements should be used when practicable, as they are smaller, cheaper, and safer than D pivot, and they impose no absolute limit to the angle of training of the gun as is the case with A pivot.

The racers are flanged; the flange is 6 inches wide and $\frac{3}{4}$ inch thick, and the rib, which is $2\frac{7}{8}$ inches wide, rises $1\frac{1}{2}$ inches above it.

SECTION OF RACER FOR MEDIUM GUNS.



The top of the flange should be laid level with the top of the racer curb, or of the concrete floor of the emplacement.

There are small bed-plates, one inch thick, under the joints of the racer and at a few intermediate positions, which aid in keeping it in position. They are fixed to the racer by screws through the flange.

For detailed drawings of these racers see I.G.F.'s Circular, No. 250, dated 26th September, 1876.

Iron Chairs for Racers.—In many situations it is inconvenient to procure stone for racer blocks. In such a case, flanged racers may be fixed to iron chairs, bedded in concrete. The chairs are of wrought iron, of the shape of an inverted U; they are three inches wide except at the joints of the racers, where they are six inches wide. They are one inch thick and one foot deep over all. The racers are fixed to them by screws and nuts; the screws are similar to those used with bed-plates when the racers are set in stone, but they have to be rather longer. Racers can be supplied either with bed-plates or chairs, as demanded.

The following table shows the number of chairs required for various descriptions of racers for medium guns :—

Letter of Racer.	Arc of Training.	Number of Chairs Required.			Remarks.
			Large.	Small.	
A	70°	Front	—	9	
		Rear	2	11	
		Total	2	20	
C	Complete Circle	Total	4	16	
D	180°	Front	2	14	
		Rear	1	8	
		Total	3	22	
D	360°	Front	5	20	
		Rear	2	8	
		Total	7	28	

Pivot Block for Medium Guns, Firing over a Height of 4 feet 3 inches.—All medium guns mounted on C, D, E, or F pivot racers require actual pivots.

The pivot consists of a cast iron block, into which a steel pivot plug, three inches in diameter, fits, passing through a plate on the under side of the slide. The pivot block is 2 feet 3 inches in diameter at base, and 2 feet $10\frac{3}{4}$ inches in total height, and set so that the top is $12\frac{1}{4}$ inches above the top service of the racer.

For a detailed drawing see Inspector-General of Fortifications Circular, No. 275, dated 13th May, 1878.

Space required by 16-foot Slide.—The spaces required to be kept clear for a 16-foot slide are as follows :—

A Pivot Emplacement.

		ft.	in.
From the front racer to the front	…	1	6
" pivot to the rear	…	20	0

C Pivot Emplacement.

		ft.	in.
From the pivot to the front	…	7	6
" " " rear	…	9	6

D Pivot Emplacement.

From the pivot to the front	…	10	0

As the radius of the path of the muzzle of a 64-pr. 71 cwt. converted in a C pivot emplacement is about 10 feet 6 inches, it follows that it is just possible to use the C pivot for this gun when 180° training are required, but the tail of the slide must be traversed clear of the parapet before running the gun up.

Six-foot Parapet Slide.—An improvement in the 16-foot slide has been adopted, which gives much more security to the gun detachment than they formerly possessed ; it is commonly called the "blocked up" slide. It consists, firstly, in blocking up the slide, thus enabling the parapet to be raised to a greater height above the top racers, and thereby giving the detachment protection against projectiles not having a falling trajectory ; and secondly, in altering the elevating gear so that the gun can be loaded under cover at depression. The dwarf platform is raised by an additional 1 foot $10\frac{1}{2}$ inches ; this enables the gun to be fired over a parapet 5 feet $10\frac{1}{2}$ inches high above the top of the racer, and, therefore, 6 feet above the racer blocks. The gun is loaded at an angle of depression of 20°, by means of a jointed rammer ; the sponging being done with a rope-handled sponge. The pivot block used is a "high" one, originally designed for use with another mounting, whose top is 18·375 inches above the top of the racer. It has to be bushed to take a 3-inch pivot plug, and since the pivot plate of the platform is 1 foot 8 inches above the top surface of the racer, the difference between this and 1 foot 6·375 inches, namely, 1·625 inches, has to be made up by a flange on the top of the bushing.

The 80-pr. converted R.M.L. gun, firing 20 P., can be fired from off this mounting without any jump of the slide.

This improvement can be applied to all emplacements, whatever the letter of the pivot may be. With a C pivot, the radius of the emplacement should be 9 feet at top, and the parapet may have an overhang of 6 inches. With this pivot, also, a small sunken way, three inches deep, may be carried round outside of the racer blocks, so as to gain a little additional cover. The depth of three inches should not be exceeded, or the loading becomes inconvenient.

New Patterns of Slide.—Patterns of slide which are being substituted in some cases for the old 16-foot one, are the shortened 13-foot and the shortened 11-foot.

Shortened Slide, 13-foot.—The shortened slide, 13-foot, is adapted for use with the converted 64-pounder and 80-pounder guns, and with the 7-inch R.B.L. It is the old 16-foot slide with three feet cut off from the end, and provided with a hydraulic buffer; and with the wooden sliding carriage replaced by a wrought iron one.

The use of the hydraulic buffer enables the recoil to be resisted in a space of 4 feet 6 inches, instead of 6 feet 6 inches.

Height of Sill for New Casemates.—The gun will fire over 4 feet 3 inches, or over 3 feet 6 inches; the latter is an improved dimension for a casemate, and all new casemates for medium guns should be built with this height of sill, instead of 2 feet 3 inches.

Racers.—The slide works on the same racers as the old 16 foot.

The advantages gained by reducing the length of the slide are that with the casemate slide, less room is taken up, and thus, if wished, the size of the chamber in which it works can be reduced; and that with the dwarf slide, it can, when on a C pivot racer, work all round the circle, so that with the shortened 13-foot slide the D pivot is no longer necessary.

Shortened Slide, 11-foot.—The shortened slide, 11-foot, was intended to take the 7-inch R.B.L. gun, and was designed to provide a mode of mounting for this gun, which would admit of its being easily blinded when used in the flanks of works. The dimensions are therefore as small as possible. This mode of mounting was only for use in Great Britain, as the 7-inch R.B.L. gun is being withdrawn from all foreign stations, but it has proved possible to work a 64-pounder R.M.L. gun on it, and it can, therefore, be used generally. The space in the front of the muzzle is, however, cramped, and its employment with a 64-pounder is not recommended.

Racers.—The gun will fire over a sill 3 feet 6 inches high. The racers are of the same section as the others for medium guns, but are only A pivot, and are of special radii, 5 feet and 14 feet.

Blocked-up 11-foot Slide.—This slide can be treated like the 16-foot slide, and blocked up so as to allow the gun to fire over a six foot parapet. This has been done in a few cases.

It has been decided to utilize for this mounting in some situations the carriages and slides of the 7-inch $6\frac{1}{2}$-ton guns from the Navy. The radii of the racers is unchanged. The length of the slide is 12 feet 6 inches, but it projects more in front of the front racer than the 11-foot slide does.

The drawing of a Haxo casemate to take this mounting is reproduced (*Plate* X.). It may be useful in some situations for interior dimensions, but, as drawn, it would be weak against modern fire.

Six-foot Parapet Slide (*Plate* VIII.).—The 6-foot parapet slide was especially designed for use in coast batteries, and for this purpose initiated a mode of mounting that was a great improvement on former patterns. It is described in this place in order to keep all the modes of mounting medium guns together. It was of novel construction and mode of working. The material is wrought iron. The carriage is mounted on live rollers, so that no tripping levers are wanted; at the same time the carriage will hardly run up of itself, as the slope of the slide has been reduced from 4° to 3°; this, however, is considered rather an advantage, as the gun can be easily and gently run up by using the running back gear. In the original pattern the recoil is checked by a circular hydraulic buffer, a device which, though not found to be suitable for heavy guns, is successful on this scale, but being very expensive has been used in very few instances. It would take some time to describe the circular buffer in detail, but it is circular in form, very compact, and is worked by a rack fixed under the carriage.—See *List of Changes*, 1st May, 1881.

Racers.—The slide is 13 feet 2 inches long, and is mounted on the same racers as the old 16-foot one.

Pivot Block.—The pivot block is, however, 18·375 inches high instead of $12\frac{1}{4}$ inches. It takes a pivot plug four inches in diameter instead of three inches, which the low one requires. These pivot blocks cannot, therefore, be made interchangeable simply by setting them at a different height above the racer.

In consequence of the carriage being on live rollers it is possible for this mode of mounting to be used in a C pivot emplacement, with all-round fire; for there being no tripping levers, it is not necessary to provide space for their use.

The gun, with 5° depression, can fire over a height of six feet above the racer. Loading is effected by the muzzle being depressed at an angle of 22°, and the charge being rammed home from behind the parapet, with a jointed rammer. The gun has been fired at a depression of 22° 42′, without causing any injury to the carriage. In addition to the six feet of cover obtained by the carriage and slide, the racer blocks can be set about $8\frac{1}{2}$ inches above the general level of the floor of the emplacement. The numbers working the gun are therefore in perfect security from everything except vertical fire, the only operations requiring a man to show himself being laying, serving the vent, and priming. The gun is of course exposed and must take its chance, but a large amount of security is obtained without having the complications of the disappearing systems.

The guns to be mounted on this system were the wrought iron 64-pounder of 64 cwt., and the 80-pounder converted, firing a 20 lbs. charge.

Slide, 6-foot Parapet for 7-inch R.M.L., 6½-ton Gun.—After the 64-pounder mounting was designed it was decided to construct a similar carriage for the 7-inch R.M.L. of 6½ tons, and to mount the latter in places approved for the wrought iron 64-pounder, and this gun and mounting has been very generally used for the auxiliary armament in coast batteries.

The radius of the C pivot emplacement, which should always be used with this mounting, should be 9 feet at top, and it may have an overhang of six inches.

Ring bolts for traversing tackle should be fixed at a height of 1 foot 8 inches above the top of the racer.

The loading is done with a sponge having a wire rope stave, and a jointed rammer. The length of the rammer when folded up is 34 inches; it is to have four joints, one 2 feet 7½ inches long, the others 2 feet 7 inches long. The recoil for loading would be from 5 feet 6 inches to 6 feet. The recoil and the length of the rammer, govern the size of the emplacement.

In an emplacement of the dimensions given above, there is space for any of the medium R.M.L. guns to be mounted, and the overlap of the muzzle will be sufficient even for the shortest of the 64-pounders.

Colonial Carriage.—Several carriages and slides for 64-pounder guns have been constructed and used in the defence of our Colonial harbours, on which the gun fires over a height of 5 feet 6 inches above the racer. The gun is loaded from behind the parapet at an angle of depression of 16°, a small loading way, 10 inches deep, being carried round between the front racer blocks and the parapet; the men actually engaged in loading have therefore 6 feet 4 inches of cover.

The carriage and slide are of iron, but the carriage is not alive; consequently when the gun is required to fire over a large horizontal

arc, a D pivot emplacement has to be used, otherwise there would not be room enough in rear of the slide to work the tripping levers.

The radii of the C pivot emplacement are 8 feet at top and 8 feet 6 inches at bottom; those of the D pivot are 11 feet and 11 feet 6 inches.

The high pivot block is used; the racers are the same as for the other 64-pounder slides.

The design for this mounting was made before that for the 6-foot parapet slide, and it will not be repeated, but it is described here as there are a good many guns mounted in this manner. It is now proposed to bring them to England, and to mount them here.

Slides for Siege Batteries.—In siege batteries, and in the counter-batteries of a similar nature thrown up by the defence, some of the guns might be mounted on carriages and slides. In this case, as they would not be required to fire over large arcs, small pieces of racer would be used which could be spiked on to a wooden framework. Spare pieces of A pivot racers should be kept in fortresses for this purpose.

Disappearing Carriages.—The disappearing carriages at present in use for M.L. guns are two in number, the counterweight carriage and the hydro-pneumatic siege carriage. There are no new ones coming on; and the place of the counterweight carriage has to a great extent been taken by the "blocked up" slide.

Counterweight Carriage.—The counterweight carriage of Major Moncrieff's invention is used for the converted 64-pounder R.M.L., and the 7-inch R.B.L. guns.

It consists mainly of two parts, the platform and the elevator.

The latter serves the part of a carriage, and also contains a counterweight, by giving motion to which the force of recoil is absorbed, and which, by its preponderance, brings the gun back again into firing position. The gun when up can fire at 5° depression over a parapet 9 feet 4 inches high (*Plate* IX.); when down its axis is about 4 feet 9 inches above the ground in a convenient position for loading.

Sweep Plates.—The platform traverses on cast iron sweep plates, 12 inches in breadth. The radii are for the front sweep plate 8 feet 11 inches, and for the rear, 4 feet 8½ inches. There is a zinc graduated arc let into one of them.

Emplacement.—The emplacement is a pit with overhanging concrete walls, and may be either a complete circle for all round fire, (though this is very undesirable) or open in rear for arcs under 180°, the proportions being slightly different in the two cases.

The drawing (*Plate* IX.) shows the plan and section of an open counterweight pit, of which the radius at top is 8 feet 6 inches, and that at bottom 12 feet; the amount of overhang being thus 3 feet 6 inches.

The all-round pit is 9 feet 3 inches radius at top, and 11 feet 8 inches at bottom.

The sides should be made from 5 to 10 feet thick, and as far up as the beginning of the overhang may be built in brick or stone or any other convenient material, but the overhang is best built in Portland cement concrete, so as to form a monolith more difficult to break away.

The strength of this construction was considerable against old guns, but is not of much account against the new ones or against new explosives.

No more pits for guns on counterweight carriages are likely to be built, for the carriage is heavy and cumbrous when compared with the gun it carries, and it is not suited to resist present modes of attack on land. These emplacements are, nevertheless, described, as they illustrate a type of construction—the concrete pit with an overhanging wall—which has been somewhat largely used.

Hydro-pneumatic Siege Disappearing Carriage for 64-pounder R.M.L.—The hydro-pneumatic siege disappearing carriage when approved was intended to be mounted in permanent emplacements in several of our forts, but difficulties occurred in connection with their design which have not been overcome, and the few carriages made form part of the siege train.

It was designed to take the wrought-iron 64-pounder R.M.L. gun, firing 12lbs. of powder, but 25lb. charges have been fired from the gun mounted on the experimental carriage without doing any harm, and it is now approved for use with the 6·6″ R.M.L. gun, firing a 100lb. shell, and 25lbs. of P powder. An 8-inch rifled howitzer has also been fired off it. It seems to absorb strains in the most wonderful way, and, moreover, from the easy nature of the first motion of the recoil it increases the accuracy of the fire of the gun mounted on it in a noticeable manner.

The carriage is somewhat similar in appearance to an ordinary travelling carriage, though much more strongly constructed. The gun, however, is carried at the ends of two long arms, which are pivoted on the same axle as the wheels. The upper ends of these

arms are connected with the rod of a piston, which works in a copper cylinder attached to the trail; the cylinder is nearly vertical, but is capable of motion about trunnions to enable it to accommodate itself to the varying positions of the piston. Internally, the cylinder is divided into two portions by means of an inner annulus; the centre portion is filled with water and glycerine, the outer with compressed air.

When the gun is fired the arms on which it is carried rotate about the axle, driving home the piston, and forcing the water into the outer space of the cylinder, thus still further compressing the air. The expansive force of the air is thus rendered sufficient to force back the piston and raise the gun again into the firing position. When the gun is down it can be retained in that position to load. The carriage cannot be easily moved about, or the gun placed anywhere to fire without preparation. It is heavy, weighing 50cwt. without the gun, and, I believe, mechanical appliances are required in order to limber up.

From the need there is of leaving a space between the parapet and the wheels, to enable the men to get round to load, it is necessary, in order to get sufficient overlap of the muzzle over the crest, that the interior face of the parapet should be vertical or have a slight overhang; that is to say, it must be revetted.

Moreover, the carriage does not absorb the force of recoil in the way in which the counterweight carriage does, but requires an anchorage, the strain on which would be 19 tons if the anchoring ties were led from the axle of the carriage at an angle of 35 degrees with the horizontal, though it is considered desirable to have two anchorages, one vertical, the other horizontal. This anchorage can be improvised in a battery by burying baulks of timber and heaping the parapet over them, but it is not so easy to make in a permanent work where the parapet is already formed.

The height of the parapet for the gun depressed at an angle of 4° is 7 feet 2½ inches.

Light Rifled R.M.L. and R.B.L. Guns.

Light Rifled Guns.—The light rifled guns used in fortresses, are the 40-pounders R.M.L. and R.B.L., the 25-pounder R.M.L., the 20-pounder R.B.L., and the various field guns.

Slide.—The 40-pounder R.M.L. has been mounted in casemates on a slide and carriage. It was a good gun for mounting in the flanks of works, in cases when it was probable that men and not earthworks would have to be fired at; for it is sufficiently powerful at a short range and is easy to work.

It would now be superseded by the lighter Q.F. guns.

Travelling Carriage and Overbank Carriage.—All the light rifled guns are mounted on travelling carriages. The 40-pounder and 25-pounder R.M.L. and the 40-pounder R.B.L., can fire overbank. Many of the latter guns have had their breech mechanism altered so that it is now "side closing," and more convenient to handle than in the original form.

On the travelling carriage the guns would fire over a height of 3 feet 3 inches, and with the added bracket, which converts the carriage into an overbank one, they would fire over a height of 5 feet 6 inches.

The R.M.L. guns mounted overbank are depressed 20° to load. A 64-pounder on an overbank carriage has been fired at a depression of 20° without doing any harm. They would be fired off the double-decked platform, which is formed of two layers of 3-inch plank, with 4 extra pieces underneath. The size of the platform is 18 feet by 12 feet.

These modes of mounting would be used for the guns intended for the batteries thrown up between the forts, which would be of the nature of siege batteries, and the overbank carriage could also be used on the faces of the fort themselves.

The travelling carriage has the following advantages: it is simple, requires no great preparation to form an emplacement, can be brought when wanted to the point where it is to be used and removed again under cover, and with the overbank bracket fixed gives better protection than any other mode of mounting except the disappearing.

The light guns can be used either in the batteries intermediate between the forts or in the forts themselves.

It is probable that towards the end of a siege the light guns that can be run up on to the rampart for a few rounds, and then taken away again into security, will be the only ones left serviceable. Every fortress should therefore be provided with some, of a calibre and weight suited to the local circumstances.

B.L. Guns.

5-inch B.L. gun of 36 cwt.—This gun, a long breechloader firing a 50lbs. projectile, has superseded the 40-pounder for the siege train

It is mounted on a lattice-girder steel overbank travelling carriage to fire over a 6-foot parapet, and is provided with a hydraulic buffer for the purpose of checking the recoil.

The carriage works on the "Davies" platform, which is a double-decked platform fitted with a combined wheel guide and attachment for the hydraulic buffer. This consists of two steel castings, resembling wheels, which are bolted together with the platform between them, the centre or pivot being three feet from the front of the platform. One end of the hydraulic buffer is attached to this and the other end to the trail of the carriage. Steel planks are provided for the wheels and trail to rest on. The distance from the pivot to the point where the trail touches the ground is 7 feet 6 inches, and the length of recoil allowed by the hydraulic buffer is 5 feet. It results from these dimensions that an angle of traverse of 56° can be got without the trail leaving the platform, and that by widening the platform three feet on each side, or making it 18 feet wide in all, an angle of traverse of 90° is obtainable.

With this angle of traverse also, the wheels will not touch the parapet if the gun be mounted behind a straight face.

4-inch B.L. guns of 22 cwt.—This gun is mounted in a similar manner to the 5-inch B.L.

It may be conveniently noted here that a casemate or shed 20 feet long will accommodate all guns and howitzers mounted on travelling carriages, with their limbers run over the trail, shafts outwards. Fifteen feet is sufficient for the 8-inch R.How. and for the 40-pounder gun.

Disappearing Carriage for 6-inch B.L. guns.—A hydro-pneumatic mounting, designed by Sir W. Armstrong, Mitchell, and Co., has been tried with a 6-inch 3-ton B.L. gun for siege purposes. It somewhat resembles that for the 6·6-inch M.L. gun before described. It is worked on an "A piece" as it is called, which is a timber framework in the form of an A, at the point of which is the pivot. This is securely anchored down. It only allows of a small angle of training. The anchorage is partly under the parapet; it is not convenient for use in a permanent work.

Disappearing Carriages for 4-inch and 5-inch B.L. guns.—It may be assumed as certain that movable H.P. disappearing mountings for 4-inch and 5-inch B.L. guns will be introduced into the service, resembling generally that for the 6·6-inch M.L. They will probably be worked on a double-decked platform with a pivot, or on some modification of it, of similar dimensions.

Mountings on Railway Trucks.—A further step in advance that is likely to be taken for fortress guns is to arrange these mountings to be carried and the guns fired on railway trucks.

By this means the maximum mobility and power of concealment is attained, the gun being either moved laterally on the rails or taken away from them to any favourable situation in the neighbourhood to which they are not laid.

The rails would be the ordinary 4 foot 8½ inch gauge, so that the truck could be run on to any line of railway. It would not be possible to fire anywhere on the line, but at selected points preparations must be made to resist the shock of recoil. For instance, this might be done by anchoring a third rail parallel to the track, to any point of which the truck could be attached. Thus all sections of parapet in favourable situations could be made available for firing from along their whole length. The gun would probably fire over a height of about nine feet above the rails.

The carriage must be capable of traversing through a small arc when being fired off a truck. This may necessitate a wider truck than is permissible on a railway, in which case it would carry a turntable, which must be pivoted round on arriving at the firing point, and which would probably require supporting at the ends clear of the rails. These trucks might also carry howitzers, which might thus be moved rapidly from one concealed position to another.

Various combinations of carriage and truck have been designed. In one by Messrs. Easton and Anderson, the two form one mounting, and the gun is always fired approximately in the line of the rails. This lessens the mechanical difficulties, but does not seem such an adaptable fighting machine as when the two are separate and the fire delivered at or about at a right angle to the lines.

In France there is a mounting which satisfies the latter condition, but in which still the carriage and truck are combined into one. This is deficient in adaptability to irregular ground.

Turrets for Land Works.—Turrets for guns of about 6-inches calibre are being extensively used on the Continent, in works constructed under the direction of General Brialmont.

Two forms will be found figured in the *Naval Annual* for 1887, by Lord Brassey. There is no likelihood of their being introduced into the English service. I believe it to be a mistake to put so much money as this system requires into passive protection, which is always liable to be overpowered by a new weapon. It would be better to expend the sum in developing the offensive strength of the

place by increasing the number, power, and mobility of the armament.

Sufficient security can be obtained for howitzers by concealment, and for guns by rapidity of fire and mobility, which will leave them exposed to injury only for short periods of time, and the advantage of large offensive power in crushing an enemy's attack is obvious. At any rate, whatever may be required on the Continent, this is the right policy for England, none of whose works are likely to have to stand a regular siege.

Rifled Howitzers.

Rifled Howitzers.—The old pattern short 8-inch howitzer of 46 cwt., and the 6·3-inch howitzer, are mounted either on a travelling carriage like the 40-pounder carriage, or on a special bed and platform. The platform is 10 feet long and 5 feet 4 inches wide. Both these are siege mountings, and there is no form of permanent mounting for a rifled howitzer. Consequently all the preparation to be made for them consists in forming a level surface of earth behind the parapet with a good foundation to take a wooden platform.

The parapet should admit of the howitzers being fired with as little as 5° elevation, when on a travelling carriage.

On a travelling carriage the axis of the 8-inch 46-cwt. howitzer, when horizontal, is 3 feet 3 inches above the ground.

On the special bed the axis is 2 feet 3 inches from the ground; when so mounted the howitzer should not be fired at a less angle of elevation than 20°.

All the howitzer beds have been removed from the siege train and allotted to permanent works.

The 8-inch howitzer of 70-cwt., which will form part of the armament of most of our fortresses, is mounted on a travelling carriage not overbank, and has in addition an hydraulic buffer fixed underneath the carriage to be connected with a pivot to check the recoil.

The 6·6-inch howitzer will also be mounted on a similar travelling carriage.

These howitzers will both be fired off a "Davies" double-decked platform like that for the 5-inch B.L. This platform is 18 feet by 12 feet, formed of two layers of 3-inch planks, with four additional pieces underneath. At three feet from the front is a wheel-guide and pivot combined, to which is attached the hydraulic buffer of the carriage.

A few instances may be found of a pivot fixed in concrete for the 8-inch 70-cwt. howitzer. The pivot being between the wheels, the piece can be traversed through a complete circle. The axis of the buffer in this design is one foot above the ground, and the top of the pivot block to which it is to be attached is four inches above the ground. It should be capable of taking a 4-inch pivot plug, and is sunk three feet in a mass of concrete six or seven feet in diameter.

The following are some of the leading dimensions :—

		ft.	ins.
Amount of recoil...	...	4	6
Length of axle of wheels ...	...	4	3
Distance from pivot to point of trail...	...	9	4
" " front of buffer	...	2	$9\frac{1}{2}$
" " muzzle of 8-in. rifled howitzer	...	5	$4\frac{1}{2}$

A wooden platform must be laid for it, and this must evidently extend for a distance of 13 feet 10 inches in rear of the pivot; in addition a space must be left for the use of the traversing hand-spike.

A steel plate 6 feet by 1 foot 6 inches by $\frac{1}{2}$-inch is placed under each wheel and under the trail to protect the platform.

The distance from the pivot to the muzzle of the howitzer being less than that from the pivot to the point of the trail, the emplacement cannot be adapted to angle of traversing of more than about 130°, except in situations where it is immaterial whether or not the howitzer is close up to the parapet.

B.L. Howitzers.—Six-inch, 7-inch, and 8-inch B.L. rifled howitzers are under trial for use with the siege train. The 7-inch will not be repeated as it introduces another calibre.

They are weapons of greater power than the M.L. howitzers of similar calibres, and consequently cannot be fired off the "Davies" platform. It is necessary that they should have an anchorage buried some seven feet in the ground, to which the hydraulic buffer is attached by iron rods. Their accuracy is greater than that of the M.L. weapons.

Rifled Mortars.—On the Continent rifled mortars of various calibres are in use. These differ from howitzers in being lighter and firing a smaller charge, always at high angles. Their accuracy is, of course, not so great, but they can fire shells of the same size whose penetration into roofs is considerable, and whose searching power is a maximum, while they are more easily transported. They are weapons that have a distinct place in siege warfare.

Smooth-bore Guns.

Smooth-Bore Guns.—Smooth-bore guns, carronades, and howitzers, may possibly be still used for flanks and places where only a limited range is required.

All the muzzle loading guns are mounted on standing carriages, or on sliding carriages and slides, similar to those already described for the 64-pounder R.M.L., but they do not require actual pivots, and various old patterns of racer are sometimes used with them.

Thirty two-pounder S.B. B.L.—A pattern of S.B. B.L. gun has been introduced for flanking purposes. It is a converted 32-pounder S.B., with an interrupted screw breech-closing arrangement. It will fire case shot only, and uses fixed ammunition.

An addition made to the muzzle of the gun has had the effect of increasing the lateral spread of the balls from the case shot considerably, so that they will cover 42 feet at a distance of 120 feet from the muzzle, while leaving the vertical spread unchanged or perhaps diminished.

It is mounted on a platform admitting only of a small amount of recoil and compelling the gun to run up immediately after firing. It will, however, be so arranged that the gun can be held at recoil, 1 foot 8 inches back, or be run in 18 inches more, 3 feet 2 inches in all, and held there. If there be a window in the embrasure this may be convenient for bringing the muzzle within it.

The platform is 6 feet 7 inches long, and 2 feet 3 inches wide. It was designed to work on A pivot racers of 1 foot 6 inches and 6 feet 10 inches radii, the rear trucks being close to the end of the platform, but the spread of the balls is sufficient to enable the traversing to be dispensed with. The platform will consequently rest on wooden blocks in their places. It is provided with an actual pivot bolt, 2 inches in diameter, to be supplied by the Artillery, and having to receive it either a pivot bar built into the wall of the casemate, or a pivot block fixed to the floor. The height of the top of the bar or block should be $10\frac{1}{4}$ inches above the floor. The projection of the muzzle beyond the pivot is 4 feet. The height of the sill should be 2 feet $4\frac{1}{2}$ inches above the floor, and the carriage will admit of 10° elevation and 15° depression.

About 10 feet space is ordinarily required in rear of the guns for sponging, but in a chamber not giving this amount of room, no doubt a rope sponge could be employed.

The detachment consists of five men, exclusive of any at the cartridge store, but three men are sufficient at the sacrifice of a little rapidity.

The gun will fire three rounds a minute, and is simple and not likely to get out of order, in fact, just the thing for a flanking gun. Its effective range may be taken at 350 yards.

S.B. Mortars.—S.B. mortars, if any are still retained as portions of armaments, will be mounted as of old on stone or wooden platforms, 6 feet 6 inches by 9 feet 6 inches, or 12 feet square for 13-inch mortars.

It should be remembered that as mortars always fire at high angles, there is no need for exposing them to the enemy's fire by mounting them on the ramparts of a work; they should always be on the parade, or in gorge batteries, or outside the fort altogether if they can be so placed without danger of capture.

The casemated mortar batteries, such as were constructed in the Portsdown Hill works, are not now used; they would not be secure against the curved fire of guns and rifled howitzers.

Quick-firing Guns.

The quick-firing guns at present in the English land service are the 3-pounder and 6-pounder. Both the Nordenfelt and Hotchkiss guns are used, as they fire the same ammunition.

Three-pounder Q.F. Travelling Carriage.—The 3-pounder Q.F. gun is mounted on a light travelling carriage, designed by Mr. Nordenfelt, to fire over a 3-foot 10-inch parapet. It is provided with a limber and could probably be transported by a couple of horses.

Six-pounder Q.F. Elastic Frame Mounting.—The 6-pounder Q.F. gun has too violent a recoil for a light travelling carriage to resist without moving, and thus rendering it necessary to relay the gun at each round. It is, therefore, mounted on a fixed conical framework, called an "elastic frame" mounting, because the spring of the metal is utilized so as to avoid the necessity of having a carriage with recoil buffers. The spring of the metal alone is not, however, sufficient for this, and, for land-works, the frame is therefore bolted to a wooden platform (*Plate* XII.), which yields at each discharge.

The "elastic frame" was originally a naval mounting, when it was assisted by the elasticity of the deck.

The gun fires over a height of 3 feet; a clear space within a

radius of 6 feet from the pivot is necessary for working it, and this space should extend 2 feet to the right and left of the axis at extreme lines of fire.

The gun can be mounted to fire through an arc of 160°, but not conveniently more, as the distance from the pivot to the muzzle is 6 feet, which is just the same as the radius of the space required to work in, and the muzzle at larger angles of training would therefore come inside the parapet.

Six-pounder Q.F. Embrasure Mounting.—It has been found desirable in some cases to mount 6-pounder Q.F. guns on saddles attached to the sills of the embrasures in iron forts. The mounting devised for this purpose by Mr. Nordenfelt admits of 4 inches recoil, while still allowing the use of a shoulder-piece for aiming, and of a pistol grip for the trigger, two great conveniences when firing rapidly. This mounting is so satisfactory that it is likely to be used in combination with the "elastic frame" mounting, so that a certain and sufficient resistance shall be given to the recoil without any risk of overstraining the frame.

New Quick-Firing Guns.—There can be little doubt that within a few years almost all artillery will be quick-firing, up to and including guns firing projectiles of about 100lbs. weight, and that possibly guns of the older patterns will be converted to quick-firing.

Rapidity of fire alone is of great value at almost all times for the navy and for coast defences, and will very often be found useful for field, siege, and garrison work, but, besides this, the manipulation of the gun becomes easier, and much smaller detachments are required. A smokeless powder is certainly required, in order that the full value of quick-firing weapons may be secured, but progress is being made with this also, and it is not likely that it will form any obstacle to the introduction of the guns.

As is usually the case when there is a new departure, there are numerous patterns of guns and mountings put forward for adoption.

The 4·7-inch Q.F. gun has been introduced into the service for the navy; a number have been ordered, and only a few minor details remain to be settled. Its projectile weighs 45 lbs., and it has fired six aimed rounds per minute. The projectile and charge are loaded separately.

This gun began as a 30-pounder and was accompanied by a 70-pounder, which is now practically defunct, having been superseded by the 100-pounder Q.F. gun. This gun would fire the same projectile as the service 6-inch B.L., which is a great advantage for supply. The gun under trial is expected to give a muzzle velocity of 2,400 feet a second, and to fire eight rounds a minute. The shot and cartridge would be separate on account of the weight, which renders a combined charge difficult to handle, and seems to make this the limit of quick-firing guns worked by hand.

I will not venture to prophecy as to what may be done by the application of power to the lighter classes of armour-piercing guns.

It has been suggested that a 14-pounder and a 40-pounder were the right quick-firing guns to use afloat.

The 40-pounder has been forestalled by the 4·7-inch gun, but there is a field for the 14-pounder, and it was proposed for the land service for flanking lines of mines where the ranges were too long for the 6-pounder Q.F. It is loaded with a combined cartridge and projectile like the 6-pounder. It is used in the Colonies.

At the Royal Arsenal a 12-pounder R.B.L., the old "Armstrong" field gun, was tried as converted into a Q.F. gun primarily for the defence of mine fields.

Mr. Maxim has "automatic" firing 3-pounders and 6-pounders, and he meditates extending this principle to higher calibres. The gun goes on firing itself until it is stopped. A rate of 36 aimed shots a minute from the 3-pounder is expected.

Efforts have been made to adapt the 4-inch 25-pounder, the 5-inch 50-pounder, and the 6-inch 100-pounder B.L. guns for quick-fire, and it can be done, but new carriages are necessary to obtain the full value of the principle.

For field guns the quick-firing principle has not been looked upon with so much favour as for others, and this for two reasons. One is that shrapnel is the projectile for field guns, and it requires a time fuze to be set for every round. The time necessarily taken to do this would, it is urged, nullify the rapidity of fire, and this would, no doubt, be the case in firing at small detachments on the march, but would not be so against large bodies of troops or against men in a position. In these cases several fuzes can be bored to the same length, and several rounds fired in rapid succession.

The other objection is the difficulty of keeping the carriage motionless after each discharge, which must be done, since any movement would render relaying necessary.

Mr. Nordenfelt has proposed an 8-pounder Q.F. gun as the heaviest that in his opinion can be used without encountering this difficulty. It has been tried, but has not been sufficiently successful to be adopted.

The Hotchkiss Company have proposed a 9-pounder.

It seems impossible at present to apply the principle to the 12-pounder field gun, but as this gun has fired four aimed rounds a minute in its present form, the question is not a very pressing one.

Proposed Mountings for Q.F. Guns.—Of these there are several.

Naval Mounting for 4·7-inch Q.F. Guns.—One for the 4·7-inch guns is in the service for the navy. A drawing of it will be found in the *Naval Annual* for 1887, by Lord Brassey. The mounting works on a combined pivot and clip racer, called a pivot-plate, about three feet in diameter. The gun is placed on a "rocking slide," which pivots on trunnion bearings, the gun only moving backwards and forwards on the slide, which includes the hydraulic buffer. The elevation and depression are given by rotating the slide round its trunnions by means of a shoulder piece attached to it, or by a hand wheel and gearing. The trunnions of the "rocking slide" fit into a revolving bracket, carried on the pivot plate, which can be trained horizontally by means of the shoulder piece or by gearing. The use of the shoulder piece enables the gun to be fired like a small arm. The mounting is partly protected by a 3-inch plate and partly by a bullet proof hood, all revolving with it. The gun is fired by electricity, so as to avoid the danger of having percussion caps in such large cartridges.

If mounted in this way on land the gun would fire over a 3-foot parapet, and would require a clear radius of 8 feet from the pivot for working it in. Very solid foundations would be required for the pivot plate.

The 6-inch 100-pounder Q.F. gun would also be provided with a similar mounting. It would require a radius of 9 feet to be kept clear.

Pillar Mounting.—The principle of this mounting is the right one for Q.F. guns, and it is likely to be considerably developed. It has been adopted by the Australian Governments for 12-pounder Q.F. guns. It consists of a movable cylinder sliding in a fixed vertical one, the top of the latter being flush with the ground. The movable cylinder, which is counterpoised, carries the gun with its elevating and traversing gear. When the movable cylinder is down the gun is concealed behind the parapet. When up, it is raised into the firing position.

The mounting is suited to the conditions of a Q.F. gun, which cannot disappear from view between each shot without losing its distinctive characteristic of rapidity of fire.

For a 6-pr. Q.F. gun the fixed cylinder is 6 feet long and 3 feet 6 inches in greatest external diameter. This admits of a rise and fall of 2 feet 6 inches. The lower cylinder must be solidly imbedded in concrete. The counterpoise arrangement is contained in the interior.

These dimensions result in a parapet 4 feet 8 inches high above the top of the fixed cylinder. This is enough to cover the guns, but the gunners must step down to a lower level on ceasing fire. This lower level would also be convenient for the ammunition service.

This mounting has been actually applied to the 6 and 12 pounders, and to the 4·7-inch Q.F. gun. The emplacement for the latter will probably be circular, eight feet in interior diameter and with a parapet six feet high. The firing number will stand on a movable stage running on rails round the mounting.

Tourelles.—The "tourelle," or small turret for a Q.F. gun such as the 6-pounder, is in my opinion almost a necessity as part of a strong land fort.

There is more than one pattern in existence, as they are used by General Brialmont in his works on the Meuse and elsewhere, but they are not yet introduced into our service.

The first described here is a *tourelle à eclipse*, or disappearing turret, designed by Mr. Nordenfelt to contain one of his 6-pounder Q.F. guns.

It consists of a cylinder of steel 10 feet high and 10 feet in interior diameter, curving inwards at the top, where there is an opening about 6 feet 6 inches across. This cylinder is embedded in concrete, with its top opening flush with the surface of the ground. The top opening is closed by a steel domed lid, with a rim about two feet deep projecting from it below, in shape like the lid of an earthenware teapot. Connected with this lid is the 6-pounder Q.F. gun, with its elevating and traversing gear and a counterpoise. When the gun is not in use, the lid closes the cylinder completely. When it is wished to open fire, the counterpoise is lowered and the lid with the gun raised about 15 inches. The gun is then run forward and can then be fired through a small port in the rim of the lid at from 6° depression to 15° elevation. In traversing laterally the gun, lid, and counterpoise are all moved together.

The lid is six inches thick, the cylinder is nine inches thick at the upper end where it curves in, but only two inches thick at the bottom. Access is obtained from below, where also the ammunition is stored.

Two men can work the gun. Nearly perfect security is obtained by this system against bullets, and it is said to have stood a battering from field guns. It forms a very small mark to aim at.

The chief disadvantage of this mounting is that it limits the length, and therefore the power, of the gun.

A simple tourelle, also designed by Mr. Nordenfelt, which does not disappear, avoids this. Its dimensions are generally that of the other tourelle when up. It is so small that it is easily concealed, and being simpler, cheaper, more easily worked, and with a more powerful gun, it is to be preferred.

I should not advocate employing this system for guns heavier than about the 6-pounder Q.F., although it is being largely used on the Continent for guns up to six inches calibre. In my opinion, only guns which are intended to be used against troops in the open require this amount of protection, and its application should consequently be limited to the smallest weapon which can give an efficient shrapnel fire, which at present seems to be the 6-pounder Q.F.

Wall Pieces.

Wall Pieces.—Experiments have been made with a view of procuring a good pattern of wall piece for firing at the heads of saps and such points, for which purpose more penetration is required than can be got from a rifle bullet, but for which the projectile from a field gun even would produce an unnecessarily large effect. The results as yet have not been very satisfactory, but the subject is likely to be solved by the use for this purpose of the smaller Q.F. guns; such as the 3-pounder.

Machine Guns.

Machine Guns.—The earlier forms of machine gun, such as the old pattern Gatling, were not sufficiently trustworthy in their action to be taken into serious consideration in deciding on the armament of a work. The design and construction of machine guns has, however, materially improved of late years, and there is now more than one form that can be depended upon to deliver a continuous fire; which is not liable to get out of order; and which can be easily set to rights if it does.

Consequently, machine guns are coming into general use as a portion of the armament of works, and it is to be hoped that their employment will be greatly extended.

Gardner Guns.—The Gardner gun, which has been adopted into the service, is in three forms, a one-barrel, a two-barrel, and a five-barrel. The latter is for use by the navy, who want to fire large volleys; it is of different design to the other two. They fire the Martini bullet with a solid cartridge case.

The one-barrel is called a rifle of position; it weighs about 55lbs. without its mounting, and is intended to be used in places where portability is of the first importance. It will fire 160 rounds a minute easily, and can be pressed up to 200 rounds.

The two-barrel is practically a duplication of the one barrel; it weighs about twice as much and fires twice as fast.

The guns are both actuated by turning a crank on the right hand side. They pivot, both vertically and horizontally, about a point which is 30 inches from the muzzle, and about 20 inches from the rear end of the mechanism. The total width of the two-barrel, including the crank handle, is under 12 inches. The feed guide rises 22 inches above the axis of the barrel, and about 12 inches more space above it is required for entering the cartridges. The mechanism is very simple, but it is not necessary to describe it here. Two men are required to work the gun rapidly, one to point and fire and the other to feed. The above data will give some idea of the space the gun will require in a work.

Maxim Gun.—The Maxim rifle-calibre machine gun, which has also been introduced, has a single barrel and a breech mechanism which when put into action acts automatically, entering, firing and extracting cartridges by means of the force of recoil. The feed is from below, the cartridges being carried in loops on a band like an elongated bandoleer. The band is stored in a box which is placed under the gun for use.

One man is required to lay the gun and to commence and cease firing. The gun will fire 600 rounds a minute.

Other Machine Guns.—Other machine guns that may be met with are the old Gatling, the improved Gatling, and Nordenfelt guns with from 2 to 10 barrels.

The old Gatling, with 10 barrels arranged round a central spindle, is an untrustworthy weapon, unless a great deal of care and attention be devoted to it. It cannot be relied on in a critical situation.

The improved Gatling has got rid of this defect, and is better than the old one in other ways as well. They both have ten barrels, which are rotated and fired by turning a crank on the right hand side. The feed cases are placed on top of the gun.

In the Nordenfelt guns the barrels are placed side by side and the firing is done by the backward and forward motion of a lever on the right hand side of the gun. The feed cases are on top of the gun.

Mountings for Machine Guns.—The Gardner gun is mounted either on a field carriage or a "parapet" mounting. The Maxim probably the same. The Gatlings and Nordenfelts on field carriages, or in the navy on "elastic frames" like the Q.F. guns.

The field carriages vary in details, but all resemble light gun carriages with trail and limber. The guns fire over a height of 3 feet 3 inches. None of these mountings are suited for use in casemates.

The parapet mounting for the 2-barrel Gardner and the Maxim gun consists of a steel bar, with wheels at one extremity and a cross-piece ending in claws at the other. A bracket carrying the gun, with its traversing and elevating gear, slides on the bar. When in the firing position, the cross piece rests on the top of the parapet, which may be of any height used for musketry. The gun bracket is slid up to the top of the bar and clamped there. The wheels also slide up a short distance, so that the end of the bar may rest on the ground.

For travelling the gun bracket is slid down and clamped, and the cross pieces serve as a handle for wheeling the gun about.

This mounting is six feet long. It can be used at any ordinary musketry parapet with a banquette. The gun can be traversed through 180°.

The Rifle.

Rifle.—The last weapon to mention is the rifle carried by the soldier.

He, as a rule, fires over a height of 4 feet 6 inches, sometimes 4 feet 9 inches, if the superior slope of the parapet be very flat, but a less height if he has to fire downwards.

The banquette on which he stands should be 3 feet wide for convenience, but can be reduced in width if it be necessary. It is approached either by a ramp or by roughly made steps.

The breast wall of the parapet may be vertical or inclined as much as 4 to 1, according to its construction; or it may be vertical for part of its height, and finished off with a slope. It may be revetted with sods, sun-dried bricks, gabions, fascines, or sandbags, or Willesden cardboard secured by pickets, or anything else that does not splinter; or, for part of its height only, with brick or rubble. The revetment should have no special foundations, as any settlement is quite immaterial.

The crest of the parapet should not be straight, but should be finished off with a series of hummocks about 3 feet long and 9 inches high. These will give additional security to the men firing, both by concealment and by actual protection against bullets.

This is its barbette mounting, so to speak, when it is fired over the top of a parapet.

Loopholes.—In its casemate mounting it is fired through a loophole, which requires a careful description. It was the impossibility of finding any useful information about loopholes that originated the idea of this book.

Musketry Loopholes.—Plates XIII. and XIV.—The points of a good loophole are, that the man using it should be able to fire from it easily, and in the required direction; that it should not weaken the wall more than can possibly be avoided; and that it should not be easy for the enemy to fire into.

As all loopholes should be designed for the places they have to occupy, it is not possible to give a recipe for their construction, but only the general principles which it is necessary to observe.

In the first place, 3 feet of wall space is required for each man at a loophole, and this is, therefore, the minimum distance from centre to centre at which they should be spaced. It must be remembered that as a man fires from his right shoulder, he requires more room on the left of the line of fire than on the right, therefore, when a loophole is next to a wall, the wall must be at least one foot from the side of it if on the right, and two feet if on the left of the loophole.

For a man armed with the infantry rifle, the neck, or narrowest part of the loophole, should be at most 2 feet 6 inches from the inner face of the wall. If providing for a work to be defended by men with carbines, it must be one foot less.

It will be found that a 4-feet wall is about the thickest through which it is advantageous to make loopholes at 3-feet intervals, unless the splay is very slight.

With a thicker wall this interval cannot be retained, and the best mode of treatment is to form arched recesses, so as to obtain thinner walls in which to make the loopholes.

In order to prevent the enemy firing into the loophole, or in any way injuring the man behind it, the opening should be as small as it can be conveniently made, its shape should be such that bullets cannot glance in, and the sides should be so formed, and of such materials, that they may not be liable to give off splinters.

A convenient way of making the neck of the loophole is to cut an opening out of a piece of half-inch iron plate, which can be built into the wall. The opening may be 12 inches by 3 inches for an ordinary straight loophole for firing down a ditch. This is larger than is absolutely necessary for the rifle, but it is well not to hinder a man more than can be helped from seeing what he has to fire at; besides, it allows for men of different heights using the same loophole conveniently.

The use of the iron plate for loopholes may be recommended in walls 4 feet or 3 feet 6 inches thick; in 3-foot or thinner walls the neck of the loop can be placed close to the outer face of the wall, and it is simpler to construct the whole in brick or masonry, or whatever the general material used may be.

In order to prevent splinters being broken off the front of the opening and finding their way in, the materials used should not easily fracture when struck by bullets, and should not have sharp angles. Almost anything may be used so long as it does not flake and splinter.

To prevent bullets glancing in, it is advisable to step the exterior when a wall is over 3 feet 6 inches thick. A brick loophole must, of course, be built in rectangular steps (*Plate* XIV.); a stone or concrete one can be sloped off in the manner shown in the drawings (*Plate* XIII.), the slope being directed towards the outer edge of the iron plate, thus precluding the possibility of a bullet glancing in, and by making the angles more obtuse, rendering them less liable to chip.

It is still possible, of course, for a bullet to glance in off the sides of the loop which are perpendicular to the iron plate, but it would have to be fired very much from one side to do so, and then would not enter with a high velocity.

In order to get the maximum of effect from a loopholed gallery, all the loops should be designed for the position they occupy, so that none of their limited arc of fire may be thrown away; thus the loops at the ends of a set firing down a ditch would be skewed inwards, while the centre ones would be straight.

Loops with extreme depression are sometimes required to see into dead angles. In designing these, care must be taken not to facilitate the enemy's firing up them (*Plate* XIII.).

Horizontal or Vertical Loopholes.—A choice must be made between horizontal and vertical loopholes according to the purpose to be served.

For the flank of a ditch, where only a limited lateral range is required, and where it is desirable to be able to strike any part of the counterscarp or escarp, vertical loopholes are most suitable.

For a gorge wall, where it is required to fire over the ground outside a fort, but not at a long range, a horizontal loophole is best.

The height of the latter should be from three to four inches, just enough to allow of aim being taken. The length will depend on the amount of lateral range required.

It may be of use to remember that the diameter of the front part of the stock of a rifle is about $1\frac{1}{4}$ inches, and the diameter of an ordinary lead pencil is $\frac{1}{4}$-inch, therefore, in drawing loopholes to a scale of $\frac{1}{5}$th, the pencil may be made to represent the rifle, and by laying it in different positions on the paper, it can be seen if there will be room enough to use the weapon conveniently.

2.—MINES.

Mines.—Mining forms a mode of attack and of defence that has been less modified by recent improvements in war *materiel* than any other. Rifled guns do not affect it at all. High explosives, such as guncotton, can only be used in it to a limited extent; their sudden action is not so well suited to displacing earth as that of gunpowder, and no satisfactory mining machinery for use in the field has as yet been invented. Even if such machinery were designed, it would only have the effect of increasing the area of the ground over which mining operations took place, but would not modify the principles on which they are carried out.

Mining will be resorted to both by the attack and by the defence; the former in order to blow in the counterscarp, and descend into the ditch, the latter in order to delay the approach of the enemy by forcing him to stop his trenches and to adopt slower methods of advancing. To a considerable extent it puts both sides on an

equality again, after the fire of the defence has been silenced, though the attack will have the advantage of being able to explode larger charges, forming craters, while the defenders must be careful to produce as little surface effect as possible.

Defensive Mines.—Preparations in a permanent form for mine defence need only be applied to such forts as are liable to a close attack, and should be simple, as the exact nature of the defence cannot be foreseen.

It does not appear advisable to attempt to build all the mine chambers that might be required, or even all the galleries, but merely to construct those main galleries which will form means of communication, and convenient starting points for mines, whatever may be the direction of the attack.

Principles of Construction of Countermines.—The galleries should be laid out in accordance with the following general principles:—

1. The chambers may be advantageously placed in one plane at a depth below the surface of from 12 to 18 feet.

The largest charges which it appears generally advisable to use in defensive mines are those for common mines, namely, those whose craters have a diameter equal to twice the line of least resistance or LLR. These will destroy galleries directly under them, at distances at least equal to their lines of least resistance. The besieger, therefore, cannot pass in safety under them without descending to a depth of more than from 24 to 36 feet.

2. Galleries should present their ends rather than their sides to the besieger, because they are then less liable to be destroyed by his mines, and the portion uninjured remains available for subsequent operations. Moreover, a gallery parallel to the place, if captured by the besiegers, might be blown up and converted into an open trench, and used as part of his approaches.

3. Galleries which are intended to be preserved when common mines in their neighbourhood are exploded, should be at a distance from them of double their lines of least resistance.

4. Galleries should not be so far apart as to admit of the besieger passing between them without being heard from one side or the other. The distance at which work may be heard, when carried on in the usual way, is about 40 feet; when the workmen endeavour to make as little noise as possible, it will not be heard for more than 20 feet.

5. No gallery should extend more than 40 or 45 yards without being crossed by some other gallery, as beyond that distance it becomes difficult to ventilate.

Plan of Countermines.—Following these principles, it appears that if the mines do not extend to a distance of over 40 yards from the place, they may consist of galleries parallel or radiating, independent of each other, and with branches from them at intervals, whose direction should be inclined to the front. The branches should also be inclined upwards, so that the mines may be placed at a convenient depth, 12 to 18 feet, while the main galleries may be kept at a lower level, where they are less likely to be injured.

If the system of mines is to be more extensive than this, the main galleries must form in plan a series of lozenges or hexagons, or portions of such, with acute angles pointed away from the place, and from these galleries would issue the branches as before.

The most convenient starting point for a system of mines is a gallery parallel to the ditch.

This may be either an ordinary counterscarp gallery, or what is better, as giving the besieger less facilities for blowing in the counterscarp at the end of the war of mines, it may be at some distance in front. The ends of this gallery must be conveniently and safely accessible from the interior of the work.

Sometimes the mines may be started from the ditch, the counterscarp being formed by a counterarched revetment.

In laying out a system of mines, the distance apart of the branches depends on the radii of effect of the charges which it is intended to use, as the defender should not, by the explosion of one of his mines, injure any part of the rest of his system, while at the same time there should be no gap in the disposition of the defences through which the mines of the attack may penetrate.

Charges of Mines.—The actual distances depend on the line of least resistance of the mines. Common mines are usually employed in the defence. The charge in ordinary soil is $\frac{1}{10}$ LLR.^{3}, their horizontal radius of rupture is $\frac{7}{4}$ LLR., and the vertical is $\frac{7}{5}$ LLR.

When designing mine galleries for any particular locality, a few charges should be fired in the same or similar soil to find the proper proportion of the LLR.^{3} that should be used.

Construction of Galleries.—The galleries should be six feet high and three feet wide, and chambers should be made at their intersections to serve as depôts of stores and materials. Grooves should be provided in the walls, eight or nine inches wide and deep, to facilitate tamping, and strong loopholed doors should be hung at the important intersections of galleries.

Provision should always be made for draining the mines, or they will never get inspected.

The galleries should be built with sufficient strength to resist the long continued pressure of the earth on their sides, which will otherwise gradually close them up; and this may happen without being noticed and repaired, for mines are not much looked after.

Plans of Mines.—Accurate plans of the mine galleries, with levels of the galleries and of the ground above, are essential, and these should be kept corrected up to date.

Positions of Mines.—With regard to the positions of mines in connection with works, they should be placed in front of the faces and shoulders of forts and before the salients of continuous lines.

A row of mines down the ditch would form a considerable obstacle to an assault. The galleries for them might be constructed during the progress of the siege. The enemy should certainly be led to imagine that they are there, even if they do not exist, as nothing is more likely to demoralize the storming party than the fear of mines. They should be placed about 10 feet in front of the escarp, if there be one, and five or six feet below the bottom of the ditch, so as to clear a breach by their explosion.

Charges might advantageously be sunk in the glacis in advance of the galleries and connected by wires with the fort. The firing of these would induce the besieger to suppose that the mine galleries extended further out than they really did, and would put him to a large amount of additional labour in mining against them.

Land Mines.—Small mines containing 6 to 8 lbs. of high explosive have been introduced into the service. They are fitted with electric fuzes, and are fired either by treading on an electro-contact apparatus or by pulling a trip line. They might be advantageously used in the glacis of a fort in advance of a line of obstacles. Care must be taken that they are not exposed to any violent concussion.

3.—ACCOMMODATION FOR GARRISONS.

Dwelling Casemates.—Dwelling casemates should conform as far as possible to the recognized dimensions for barrack rooms, and should have the usual barrack fittings, for which see the *Synopsis of Barracks.* Those for the men should be 20 feet, or if possible 22 feet wide, and 12 feet high in the centre.

They should not be more than 45 feet long, or they are difficult to ventilate, and become unhealthy; 35 feet is a good length to accommodate 12 men.

Long casemates should have a passage separating the ends from the earth at the back; this helps to keep them dry, and to ventilate them, and also forms a secure communication in war time.

Besides the large casemates for the men, it will be convenient if a certain number of small ones, say of 14 feet span, are provided for officers, staff-sergeants, etc.

Accessory Buildings.—The accessory buildings, such as cookhouses, may either be bombproof, or be of light construction. On the one hand, it is always advisable to have as much bombproof accommodation as possible in a fort, and of course cooking will have to be carried on during a siege; on the other hand, a light building is cheaper to build, and is often pleasanter to use, and more convenient in peace time.

Each case must be decided on its merits, but the necessity of cooking in war time must not be overlooked.

Latrines.—With regard to latrines, we used to be taught at Woolwich that a fortress once surrendered on account of these being all destroyed by the enemy's fire, and the inconvenience being so great that the garrison would not stand it. There must have been a deficiency of crockery in that fortress, or else the garrison could not have been very anxious to prolong the siege.

The example hardly proves the necessity of having bombproof latrines, although it shows the desirability of protecting them when possible.

The sanitary requirements of peace time are too important to be sacrificed, and latrines should not be placed in confined bombproofs, or in passages near dwelling rooms, where they are liable to become dangerous nuisances.

If they can be placed in small bombproofs by themselves, it is well to arrange them so.

The counterscarp of the ditch of a retrenchment is an example of a position where they were secure and handy to the men's rooms, while at the same time they were not liable to become unhealthy. The reverse slopes of the rampart would often supply a site for them.

The roof of a gorge caponier is sometimes a convenient position for open latrines.

Casemates for War time only.—While dwelling casemates should be always made as convenient and comfortable as possible, yet it may often be necessary to construct them for use in war time only.

If the face of the casemates be turned at all towards the enemy, they are liable to be struck by curved or high angle fire, and no longer give absolute security.

It may be impracticable to place them in any other position, and the only certain means of protection left is to carry an arched passage along the front.

This may be made large and wide, but it necessarily cuts off direct light, and tends to make the casemates damp and draughty. These discomforts may be endured cheerfully during a siege when perfect security is gained by it, but men cannot be subjected to them in peace time without risk of disease.

It therefore often becomes necessary to consider, in designing a fort, what casemates shall be for peace use, and what for war only. There is usually one face of a fort that is safe against enfilade and reverse fire. In that can be put the casemates for the peace garrison, which will, of course, be less than the full one, and the remainder must be considered as intended for war use only, and protected accordingly.

The greatest pains must be taken with the construction and ventilation of these covered casemates, for men can get ill from damp in war as in peace time, and the loss of their services is then more serious.

In some foreign works the expedient has been adopted of building two rows of casemates facing one another at a short distance, thus forming a sort of narrow street. In peace time this space between the casemates is left uncovered, but in war time it is intended to be roofed over with beams or girders and earth. This is suitable for isolated "barrier" forts liable to be attacked on all sides.

In war time the men can be more closely packed than in peace: the peace accommodation may be doubled for war.

Hospital.—While designing a fort, it is advisable to settle in your own mind which casemate shall be allotted in war time as a hospital for the wounded. It should be safe, light, airy, and as quiet as possible. Although not appropriated as a hospital in peace time, yet, if fit for the purpose, it will doubtless be taken during war.

Occupation of Galleries and Caponiers.—Besides occupying the casemates intended for them, men can be put up in the galleries, gun casemates, flanks, and caponiers.

The latter, indeed the flanks and caponiers, must always be occupied in war time by a guard, or at least by a sentry, so that they should be made as comfortable as circumstances will permit; there should not be a stream of water running through them, for instance, as in a caponier in one of our works.

Some of the old large caponiers are fitted up as married quarters; this is going to the other extreme. The bottom of a ditch is not a good place for a quarter, and a caponier should be a building entirely for warlike purposes. The caponiers of the present day will, however, be too small for such a use.

A loopholed gallery running along the gorge of a work, about six feet wide, and covered with earth to the front, will often be found a convenient way of combining security for the work, with accommodation for the garrison, at a small cost. It is of course not suited for permanent habitation.

Hammocks.—If it be necessary to pack the men very close, or if it be undesirable to fill the space up with beds, hammocks must be used, and arrangements made for hanging them. A hammock requires nine feet between the points of support, and a space two feet wide for each hammock is ample. It should be hung about four or five feet from the floor level.

On land, where there is no motion as in a ship, the two hammock cords need not be of the same length, but if they are not so the supporting hooks must be at different heights; their proper positions can only be found by trial.

Storage of Provisions.—Connected with the question of occupation is the supply of provisions and water. In war time a secure and dry place would have to be allotted to the storage of provisions, in amount varying with the number of the garrison, and the possibility of its being isolated.

In an ordinary detached fort one of the casemates might be told off for this purpose; in a work which is intended to stand alone special arrangements must be made.

Water Supply.—The water supply requires more careful preparation.

A fort should never run short of water; it must therefore either contain a well, or else tanks of such a capacity that they can be counted on never to run dry.

Their size obviously depends on the number of the garrison, the allowance per man, and the frequency with which they can be refilled.

Ten gallons per head per day is a sufficient quantity in peace time, and three gallons a head per day is enough to allow if it be necessary to economize. Thirty gallons per head per day is the allowance for a civil population in ordinary times.

The tanks should be bombproof, or shells may drop into them and burst and destroy the rendering of the sides, so as to let off the water.

If the tank be filled with rain water, great care must be taken in choosing the catchwater area that it be thoroughly clean, and, if possible, that it be so placed that it may remain clean during a siege.

4.—PASSAGES AND COMMUNICATIONS.

Passages and Galleries.—Passages and galleries form very important parts of a fort, and it is very necessary to have them secure and large enough for the offices they have to fulfil, at the same time not allowing them to cost more than is necessary.

Lamp Passages.—Lamp passages are, as a rule, the narrowest of all, as they are only required to admit the lamp-man with a few lamps, which are easily carried; 2 feet 6 inches is sufficient width.

Galleries of Communication.—Galleries of communication are of varying width, from 3 feet to 20 feet; the dimensions adopted must depend on the use which is to be made of the gallery.

A 3-foot passage may be used where the traffic is small, when leading to a secure place, and where it is not required to move stores; as for instance to a magazine, where the ammunition is introduced and removed by a lift, and the passage is only required for the magazine men.

The communication to a caponier, or from one exposed portion of a work to another, should be at least 4 feet wide, and always when possible 5 feet wide, on account of the difficulty of moving wounded men in a narrower space, as that is about the least width in which two men could assist a wounded comrade, one on each side.

The turns should not be too sharp, to admit of a stretcher being carried round them.

In the case of the communication to a caponier or flanking gallery which is to be armed with guns, 5 feet is width enough to admit of the guns being taken down it, and also their carriages and platforms.

In constructing galleries, it is often desirable to allow for their being used as places for stores, or even for men in war-time; the passages would of course be bombproof, and would form a secure shelter from projectiles, of which there is never likely to be too much in a work.

Seven feet of width would give room enough for a row of men to sleep without interrupting the communication, and with 10 feet they might lie side by side.

Galleries or arched passages, down which guns or any vehicles have to be moved, had better be 10 feet wide, or 12 feet if they are very long; 8 feet 6 inches is just wide enough to admit all military vehicles, but demands nice driving.

More than 10 feet is seldom required, although as an example of a larger one may be mentioned a long gallery 20 feet wide, introduced into the design for a work which was intended as a support to a number of advanced batteries; it was proposed that this gallery, besides forming a communication between the parts of the fort, should always serve as a store for the field and position guns which were to be used in the advanced batteries. The guns, with their carriages and limbers, could be ranged along the sides of the passage, and the entrances at each end were so arranged that the horses could be taken in and harnessed, and the guns taken straight out of the fort, without its being necessary to shift them by hand at all.

Archways over roads should not be less than 10 feet high.

Ramps.—Wherever it is possible, ramps should be used in galleries and not steps, for facility in moving stores. Slopes of from $\frac{1}{7}$ to $\frac{1}{10}$ will do. If it be necessary to use some steps in a communication, part of which is formed in a ramp, the steps should be placed at the upper end so as to be in the daylight.

Ramps should always be made as flat as possible, and the longer they are the flatter they should be. The steepest ramp used in a work is that leading up to the banquette, which is often at a slope of 1 in 2, but if this be longer than 7 feet, it is desirable to make it easier, or to introduce a secondary level; that is, a sort of additional banquette about 7 feet below the crest.

The ramps leading to the rampart, up which guns have to be taken, should be 1 in 10, or 1 in 12 if possible; for short distances they may be 1 in 7.

Arrangement of Communications.—The communications of a fort are, perhaps, the most difficult things about it to arrange satisfactorily, and, at the same time, on them depends more than anything else the convenience and security of the work. In the descriptions of the old systems of fortification, all the passages and flights of steps

by which the outworks were reached are carefully enumerated, showing of what importance they were considered.

It should be possible to circulate all round a fort in security, and to arrive safely near any particular point in the parapet. For this purpose at least one covered passage from the rear to the front is usually necessary.

Some of the stairs up to the terreplein might issue under cover of bombproofs; there would be others in the open air for additional convenience.

The ramps for guns leading up to the terreplein can seldom be protected otherwise than by traverses; but then the guns are not often being moved by them.

If greater security is required for them, the easiest way to attain it sometimes is to have an opening in the floor of a bombproof, and to hoist the guns up vertically.

It should be remembered in laying out communications that men will take short cuts if they can, and steps and paths should be provided accordingly, or the slopes will get cut up and spoiled in appearance. Steps may be cheaply made with wood or rough stonework.

The most difficult part of an arched communication to design is a secure exit on the side next the enemy. It should not be possible for him to enfilade it.

Care should be taken that an arched communication be not so placed as to lead the effect of any explosion that may occur in it towards a magazine.

5.—ESCARPS AND COUNTERSCARPS.

In so far as these are retaining walls, they are built according to the rules laid down in works on Civil Engineering, such as Rankine's, or in Colonel, now General, Wray's book on *Some Applications of Theory to the Practice of Construction.*

Pasley's Revetments.—General Sir C. Pasley's rules (which are good working rules) for revetments are that they should be countersloping, with an average slope of five in one, and should have according to their situation the following mean thickness:—

Counterscarp revetments, one-fourth their height.

Demi revetments, without berms, three-tenths their height.

Full revetments, or demi revetments, with berms equal to one-fourth their height, $\frac{17}{80}$ times their height.

Counterforts, rectangular, and having a counterslope of five in one. Length, one-fifth the height of the wall. Thickness, 2 feet 6 inches for a wall 10 feet high, and increased 1½ inches for every additional foot in height. Distance from centre to centre, four times their thickness.

Colonel Wray.—Colonel Wray recommends that revetments be given a slight batter on the face, not more than six in one, and points out that they should be as thin as possible at the top to use a given quantity of material with the greatest economy.

Special Treatment of Revetments.—There is a necessary difference of treatment between revetments and ordinary retaining walls, produced by the fact that they have usually to resist other causes tending to their injury besides the simple pressure of the earth, and on this a few remarks may be made.

Solidity.—In the first place a certain amount of solidity is required everywhere, irrespective of the pressures the wall has to sustain, in order that a chance blow from a projectile or the explosion of a shell in the parapet may not do much harm. With this view it is a good rule that no part of an escarp or counterscarp wall shall be less than 3 feet 6 inches thick. This will not apply to the facing which it is sometimes necessary to build over such a rock as chalk to prevent it disintegrating under the influence of the weather, and which does not add to its strength against artillery.

General Form.—In the second place a form should be chosen for those parts of the revetments which are exposed to attack, whether from projectiles or mines, which will best enable them to resist injury. From this point of view a counterarched revetment with arches running a long way back appears to be best.

If it be concealed from sight it is difficult to strike the ends of the piers or arches by fire directed perpendicularly to the line of the escarp, and the shot which do not strike are wasted.

Fire which is directed at an inclination to the general line of revetment will of course have a better chance of striking the piers, but then the number of shots will be spread over a greater length of face.

Until the arch is completely destroyed it will form an interruption in the slope of the breach, which will increase the difficulties of an assault.

There will be less filling up of the ditch from debris than with any other kind of revetment.

As to dimensions, three feet of thickness for both piers and arches

might be used. The arches should certainly be bombproof or they might be breached by high angle howitzer fire. There should be a thin screen wall filling up the intervals between the piers, so as to ensure proper flanking, and by piercing the latter with openings an escarp gallery can be easily arranged if wished.

In a counterscarp, a counterarched revetment is convenient for starting the mine galleries from.

If counterarches be not used, a simple solid revetment is, perhaps, the best; if well built it will take a great deal of pounding to bring it down.

Construction and Sectional Form.—All revetments, and indeed all work about a fort, should be built in cement, as it adds materially to the resisting power. Moreover, almost any desired form can be given to the walls without fear of the weather injuring them. If the top of the counterscarp be rounded, there will be a difficulty in getting at the head of a scaling ladder. A cordon on the face of an escarp is a good thing; it prevents a scaling ladder from lying flat against the wall, and renders it springy and more liable to be broken by the weight of the men on it; and also renders it impossible to slide the top of the ladder up into position.

If it be possible to give an escarp a facing of hard stone, such as granite, it would increase the difficulty of commencing a breach, as the shells would not bite on it easily.

It has been suggested that if an escarp were built with a large quantity of iron bars bonded into it, then, when it was breached, the iron bars would stick out of the portion left standing on either side, and that the fallen fragments would bristle with them so as to form a sort of *chevaux de frise*, rendering an assault very difficult. The idea may prove serviceable.

Height of Escarps.—An escarp 40 feet high is supposed to be secure against escalade. It should be ten feet high to necessitate ladders; with less than that men could help one another up. Fifteen feet is about the minimum that should be used. Counterscarps should be higher than this or men will jump down them without injury.

Detached Walls.—Detached walls should be angular at top, so that there may be no landing place there for men to stand on to pull ladders over. They may be three or four feet thick, so as not to be seriously injured by a chance shell, and may be loopholed. There should be a way behind them which may be traversed, if the traverses do not interfere with the flanking fire. One of the advantages of a detached wall is that its fall does not involve that of any part of the parapet; in order to secure this advantage the prolongation of the exterior slope of the parapet should not fall outside the intersection of the bottom of the ditch with the exterior of the wall.

When the wall is brought in as close as it can be, consistently with this condition, the level of the *chemin des rondes* behind is raised above the bottom of the ditch.

Detached walls are more easily breached than retaining walls, and holes may be knocked in them through which an entrance may be made. Consequently they should, if possible, be flanked on both sides.

An old front of fortification can sometimes be improved by building a detached wall in the ditch, close up to the counterscarp, where it will be difficult to strike, thus providing an obstacle in case the old rampart be breached.

Breast Wall.—Any wall which is constructed merely as a breast wall for firing over should be as thin as possible, consistent with resisting bullets, say nine inches thick. Any increase of thickness beyond this will not enable it to keep out heavier projectiles, and will only add to the number of splinters if it be struck, and to the difficulty of repairing it.

6.—FENCES.

A Railing as an Escarp.—A strong iron railing would form an efficient obstacle as a substitute for an escarp, and one which it would be difficult to breach by artillery fire, but several precautions must be observed in designing and constructing it.

It should be made of 1-inch bars of iron or $\frac{7}{8}$-inch bars at least; these should not be more than six inches apart, otherwise the bars may be bent sufficiently to admit of an entrance being made, by putting a loop of rope round two of them and twisting it tight by a stick inserted into it.

The horizontal bars which are necessary to give stiffness should be at least 5 feet apart, so as not to offer any facilities for climbing up. On the top horizontal bar spikes may be fixed between the vertical bars to prevent men standing on it.

The tops of the bars should be finished with a sharp pointed spike, and one or two spikes projecting downwards and outwards making the top like a barbed arrow would render the fence much more difficult to climb over.

Each of the vertical bars should be securely fixed in the ground

so as to stand independently of the rest. Probably the best way to do it would be to connect the verticals by a horizontal piece under the ground level, and to bed this in a mass of concrete.

It would be advisable to strut the railing at intervals, though these struts will to a small extent interfere with the flanking fire.

Angle Iron Palisade (Plate XV.).—An excellent fence is formed of vertical angle irons connected by horizontal bars at the top and bottom.

In a form which has been extensively used, the bars are alternately 8 feet and 7 feet 8 inches long, of $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch by $\frac{1}{4}$ inch L irons, split at the upper ends to form spikes, and about seven inches apart. They are connected by stronger angle irons rivetted to them close to the bottom and at about one foot below the top.

They are made up in lengths of 9 feet.

The end uprights, which are T, not angle, irons, and two of the intermediate ones, are prolonged for fixing in the ground.

Spikes three inches long are rivetted to the uprights near the top, and to the upper horizontal member.

The railing round a fort should be ordered for the exact angles, slopes, and lengths required, so that the various portions may be made to fit when set up. Otherwise they will have to be taken to pieces and re-rivetted.

Another Form.—A good form of fence can be made with $1\frac{3}{4}$-inch by $1\frac{3}{4}$-inch by $\frac{1}{4}$-inch steel angle-irons 12 feet 6 inches long. These are set upright in the ground six inches apart, and projecting about 9 feet.

They are connected at the bottom, at the ground level, and at about 3 feet 6 inches below the top by horizontal pieces of the same section bolted or rivetted to them.

Fences.—When ground has been cleared round a fort, it often has to be divided up again into fields; at any rate a boundary fence must be made. In these cases Morton's wire fencing is used, formed of No. 8 galvanized iron wire with iron uprights.

In the process of time natural causes will, if not checked, produce a new hedge where the wire fence is, by the growth of bushes under its protection. This will not, however, form a very solid barrier, and can be easily cleared away if it has been permitted to grow.

The wire fences form a sort of reserve store of wire for entanglements.

An excellent material for military fences is barbed wire, as it is so efficient as an obstacle. It consists of two twisted steel wires holding a group of four barbs ½ inch long at every three or four feet.

A single or double row of wire fencing might be used in some cases in connection with entanglements, as a substitute for iron palisading. It would offer less obstruction to projectiles fired through it by defenders against the enemy.

Wire Entanglements.—Entanglements are likely to be very extensively used in connection with the sloping sections now so much employed.

There are two kinds; one consists of stout stakes driven into the ground from four to seven feet apart in rows arranged chequerwise, and with their heads connected by strong wires crossing diagonally, twisted round the heads of the stakes about one foot or 18 inches above the ground.

In another kind the stakes are four feet above the ground, and the head of each stake is connected with the foot of that diagonally opposite it by a stout wire. These diagonal wires are again connected by thinner horizontal wires.

The difficulty of crossing an entanglement is increased by the use of barbed wire, particularly in the second form.

7.—GATES AND KEYS.

Gates.—The entrance gates of a fortification forming part of a physical obstacle, should be constructed so as to resist any attempt at storming them, even though they may be behind a drawbridge, as the latter may chance not to be raised at the critical moment (*Plate* XVI.).

Construction.—They should be strongly made, well hung, capable of being firmly closed, bullet-proof, and loopholed.

Bullet-proof.—To make them bullet-proof, they should be plated with steel ¼ inch thick at least, and it would probably be advisable to anticipate improvements in small arms, and to make the plating ½ inch thick.

If iron be used it will have to be about twice as thick.

Framing, etc.—Gates may be framed either in wood or iron. If in the former they should be solid, say three inches thick, but with ½ inch steel plates it would be best not to have any wood. Strap hinges should be used with bolts through the door, nutted on the inside.

To close them, in addition to barrel bolts at top and bottom, a swing bar should be provided similar to that used for shell recess doors, and fastened with a padlock: it might be made of 3-inch by ½ inch iron.

Wicket Gate.—All large gates should contain a small wicket in one of the leaves. This gives increased convenience and security, by rendering it unnecessary to open them so often as would otherwise be the case. The wicket may be small, say four feet high by 2 feet 3 inches wide, it must not weaken the gates, and must fasten safely. It should have a lock and key for ordinary use.

It is advisable to place any gate that forms part of the defences of a work under a bombproof arch, so that it may not be injured by a chance shell.

Gates, not Drawbridges, to be used inside a work.—For closing an interior communication, the interruption of which at the wrong time might cause great inconvenience, it is best not to use a drawbridge, but, instead, to have two gates separated by an interval of six or eight feet, the inner one being plated and loopholed, the outer one being made of iron bars, forming an open framing through which the defenders can fire. It may be made of 1-inch or ⅞-inch round iron bars, with flat iron horizontal crosspieces four feet apart, and diagonals between them. It would be almost impossible to destroy the bar gate in face of the loopholes of the inner one. Both gates should be under a bombproof archway, and the bar gate should be capable of being rapidly closed and securely fastened in such a manner that it cannot be opened from without. There are several simple ways of doing this; the exact method adopted must depend on the conditions of the particular case.

A form which I have used is as follows:—An iron bar is hinged at one end to the gate, and at the other end is formed into a hook. This hook slides on a bar fixed along one side of the entrance passage inside the gate. A bend is made in the fixed bar in such a position that when the gate is closed the hook of the sliding bar falls into it. The hook is then kept in position by a pawl, which has to be pushed while in order to lift the hook out of the bend. The sliding bar is made of such a length that the pawl cannot be reached from the outside. Consequently the gate, if slammed to, fastens itself securely, and can only be opened from the interior of the work.

Keys.—The keys form an important part of the communications of a fortress.

In time of war, easy and unimpeded access to the various parts of the works would be of the greatest importance to the defenders, and at the same time, it would be even more necessary than in peace time to lock out unauthorised intruders. The want of system shown in having an independent key for each gate would become an intolerable nuisance. All fortresses should have their locks arranged in the manner which is carried out, for example, at Malta, or at Aden. Each gate should have a lock or padlock with its own key. Sub-master keys govern groups of locks, such as those of a single fort or of an artillery district, and these can be given to persons employed only within these limits. A general master key will open any of the communication locks in the place, and anyone in possession of one of those master keys can make his way over the whole fortress without any hindrance from locked gates.

Of course these keys have to be carefully accounted for. They are given out only against a written receipt, and must be shown periodically, as if one fell into improper hands it would entail the alteration or renewal of all the locks that it governs.

The same principle is applied to the Artillery magazine and store locks, and to the Ordnance Store Department magazine locks.

In order to apply this system it is only necessary to classify the locks of a place either as "Communication," "Artillery," or "Ordnance Store," and also to settle what sub-groups, if any, are required.

Sub-groups will not be required in a small place, nor for the ordnance store locks. Sometimes sub-master keys are rendered unnecessary by making all the communication locks of each fort the same. In ordering locks, which should be done from a large maker, such as Hobbs, Hart & Co., it is only necessary to specify the class and group, and each lock will be made to fit into its proper place in this system. The keys and locks should be stamped "A," "C," or "O," and, if all different, should be numbered.

Locks.—It may be convenient here to give the rule for determining whether a lock is right or left handed. Suppose yourself standing outside the door and looking at it. There if the lock is to your right, it is right-handed, if to your left, it is left-handed. In the case of latches it must be stated whether the door opens outwards or inwards.

8.—CAPONIERS AND FLANKING GALLERIES.

As these will still be used in places where vertical escarps have been constructed, a few notes on the various forms they assume may be useful.

As no ditch defence of this nature, unless of very elaborate construction, can be expected to hold out after the enemy has effected a lodgment on the counterscarp near it, it is of no use building it with a view to resist the crossing of a ditch in force. Neither should brick or stone caponiers be employed where they are subject to an artillery attack.

Such works are, therefore, of service only against an assault or surprise.

They may be legitimately used in the case of an isolated coast battery liable to be attacked by a party landed from ships, but now hardly ever in land defences.

As a rule, rifles alone will be required in a caponier. A few magazine rifles will give an amply sufficient fire down the confined space of a ditch. Machine guns should never be used in such a situation. Their useful field of effect is so much larger that they should be on the parapet, where they would very likely prevent the enemy approaching the ditch at all.

As guns are not required to be mounted for the purpose of destroying covered communications across the ditch, they should be sparingly used. They will be required only for long ditches, where they will take effect simultaneously on a larger number of an assaulting party than rifles will. The gun to be employed would be the 32-pounder S.B. B.L., which is cheap, handy, effective, and sufficiently rapid.

No description of an iron caponier such as was formerly proposed to resist artillery fire will be found in this book. Its place in land works is taken by the "tourelle" for a Q.F. gun, which has a larger field of usefulness.

Design of Masonry Caponier.—To obtain the maximum fire it should be as long as possible; therefore the loophole at the inner end should just see down the face of the escarp, and that at the outer end down the face of the counterscarp. The gallery behind the loopholed wall must therefore be carried at least two feet within the line of the escarp, and beyond that of the counterscarp. As many loopholes as possible should be placed between them, the distance from centre to centre not being less than 3 feet.

If a gun be used, the centre of its embrasure should be about 5 feet from the escarp; this gives room for a loophole between it and the wall.

The loopholes should not be less than 1 foot 6 inches above the bottom of the ditch, or their view is easily blocked. It is best to have the floor of the gallery level with the bottom of the ditch. As the ground immediately outside the gallery should be 7 feet below the loopholes, it is usually necessary to provide a drop ditch about 10 feet wide.

The gallery may be as narrow as 2 feet 6 inches, but is best made 4 or 5 feet wide.

A 32-pounder S.B. B.L. gun requires a length of 10 feet for a width of 8 feet.

The face of a caponier should be flanked by 2 or 3 loopholes.

The end of a caponier may either be made square, in which case it should be provided with one or two horizontal loopholes for its own defence; or it may be made pointed so as to be flanked from another gallery; or it may be buried in the counterscarp if the latter is a high one. The first arrangement is usually the best.

In the case of a "single" caponier, *i.e.* one that fires one way only, it is desirable to provide for fire over its roof.

In the case of a large double caponier, which fires both ways, the end may be given an indented form.

In the case of a double caponier at an angle, it is advisable, as a rule, to make two horns of it, so to speak, and not to make a single gallery with loopholes on both sides. Injury to one half will then not silence the other, and the head can be properly defended.

The widening of the ditch round the head of a caponier should be done as far as possible without lowering the crest of the glacis, and without making the ditch at that point so narrow as to facilitate escalade. These objects may, in many cases, be combined by increasing the height of the counterscarp revetment there.

A counterscarp gallery is like a single caponier. The communication to it will be longer, as it must pass under the ditch.

Small Caponier.—With the introduction of magazine rifles it would be sufficient, in most cases, to use caponiers of the smallest dimensions; say for two loopholes flanking a wall. The head then need only project internally five or six feet beyond the face of the wall.

Caponiers are susceptible of a considerable variety of treatment, and a good deal more might be written about them; but it seems unnecessary in view of the fact that they have of late sunk to a subordinate position as means of defence.

9.—DRAWBRIDGES.

Drawbridges.—Drawbridges may be divided into four classes, "Lifting," "Rolling," "Equilibrium," and "Swing" bridges.

Lifting.—Lifting bridges are those which, being hinged at one end, have the other end raised, usually by chains attached to it.

Rolling.—Rolling bridges are not hinged, but are moved in and out with the roadway remaining horizontal.

Equilibrium.—Equilibrium bridges are such as have no counterpoise, but which are compelled to move in such a manner that the centre of gravity moves in a horizontal line; and the bridge, consequently, is in equilibrium in every position.

Swing.—Swing bridges are those that are pivoted about a vertical axis.

Lifting Bridges.—Advantages.—A lifting bridge is one of the earliest and simplest forms of military bridge. As it will work without very accurate fitting, and does not require much ironwork in its construction, it can easily be set up in out-of-the-way places; the mechanism required to move it may be simple and easily got at, and may be worked at a distance from the bridge, if wished. The bridge, when raised, covers the entrance.

Disadvantages.—The objections to it are that a long span is not practicable; that it requires a counterpoise to enable it to be easily moved; that the necessity for a support for the pulleys over which the chains pass, renders it impossible to apply this bridge except in front of a vertical wall, and that the square sinking in the face of the latter for the bridge when raised, with the two holes in it for the chains, is destructive of architectural effect.

Many forms of Lifting Bridge.—There are many forms of lifting bridge in use; it is not worth while attempting to describe them all; a few varieties only will be mentioned, and a bridge of this class described, which was set up at Fort Benjemma, Malta, which was cheap and simple, and worked easily.

Every lifting bridge should be counterpoised, so that friction only should have to be overcome in raising it, and all the variations lie in the mode of arranging the counterpoise.

The Gothic Drawbridge.—The Gothic drawbridge, as it has been called, which will still be met with in old works, is a lifting bridge, with the outer end connected by two chains with two beams overhead, which project over the bridge when it is down.

The inner ends of the beams are counterpoised nearly up to the weight of the bridge, and on pulling down the counterpoise the bridge rises.

The counterpoise is usually made by prolonging the beams, and by forming between them a barrier with a postern gate in it; and the pivot is so placed that when the bridge is up and the counterpoise down there shall be sufficient space between them in which men may move about; this gives additional security to the entrance.

The whole affair is much exposed to view from the exterior, and takes up a good deal of room. Besides this the system has the defect that the movements of the bridge and counterpoise do not vary equally, but the bridge preponderates at the beginning of the lifting and the counterpoise at the end. The practical result of this is that when raising the bridge, after struggling to start it, and using a good deal of force, the motion rapidly becomes easier, and the bridge invariably comes up with a bang, throwing all the dirt from the roadway over the lifting party.

Balanced Bridges.—Some bridges are made twice as long as the width of the ditch which they cross, and are balanced in the centre so that they may be tilted either up or down when the communication is to be broken. Those which tilt up, that is, those of which the outer end rises and the inner end falls, require a hollow space to be left behind the escarp for the end of the bridge to be depressed into. This weakens the escarp, and also prevents access to the bridge when it is raised. Those which tilt down avoid these objections.

In either case the end of the bridge which descends has to be secured by bolts, which must be depended upon to keep it in position when it is in use. It may happen that these bolts are not shot, in which case the first person that comes on the bridge is tipped into the ditch.

This is not a form to be recommended, but it is not uncommon.

Chain Counterpoise.—If a lifting bridge be made having the wheels over which the lifting chains pass placed vertically over the hinge on which the bridge turns, and at the same distance from it as are the points of attachment for these chains to the outer end of the bridge, then it will be found, on resolving the weight of the bridge in two directions (along the bridge and along the chain), that the tension of the chain is in all positions exactly proportional to the length of the chain between the wheel and the end of the bridge; consequently, a counterpoise that will diminish proportionally as the chain is hauled in will exactly balance the weight of the bridge.

This result is attained by the chain counterpoise, which is the best and simplest counterpoise for a lifting bridge.

It is arranged in the following manner: a chain of heavy links is attached to the end of each of the lifting chains of the bridge, the weight being equal to the tension in these chains, that is, on each side to one-quarter of the weight of the bridge resolved along them.

The length of the counterpoise is half that of the part of the lifting chain between the outer end of the bridge and the wheel above the inner end that it passes over, that is, half the length of that part of the chain which is visible outside the escarp; also the lower ends of the counterpoises are fixed to the wall.

It will be seen that as the bridge is raised by the lifting chain being hauled in, the top of the counterpoise descends, but the lower end being fastened to the wall, it forms a loop, the weight on the lifting chain being gradually reduced till, when the bridge is in and there is no strain on it at all, the counterpoise is hanging vertically down from the wall, and is no longer supported by the lifting chain.

It will be observed that the weight of the lifting chains is neglected; they might be counterpoised, but it would involve an additional arrangement which it is not worth while to introduce. The action of their weight is rather beneficial, as they tend to keep the bridge out when it is out, and in when it is in.

The chain counterpoises can be made in a variety of ways, and with more or less attention to appearances. The neatest form of it is that made of heavy flat links pinned together, of which there is an example at Fort Staddon, Plymouth, among other places, but a bridge is described here which was put up at Fort Benjemma, in Malta, which works satisfactorily, and the parts of which can be made in places where there are no labour-saving appliances or machine tools, for even the hinges of the Benjemma bridge were not turned, but hammered into a cylindrical form.

Drawings of the iron-work used in its construction are given, which may be found useful (*Plate* XVII.).

The movable part of the bridge is 10 feet long and 10 feet 6 inches broad, and it spans an opening 8 feet 9 inches wide. It is formed of six joists, each 7 inches by 4 inches, framed at one end into a piece 9 inches by 7 inches, and at the other into a piece 9 inches by 5½ inches. The outside joists are further secured by angle plates.

The joists are covered with boards 9 inches by 2 inches laid across, and these again by others 9 inches by 1 inch laid longitudinally. On top are screwed 2-inch by ¼-inch strips of iron to protect the woodwork. The inner edge is specially protected by a hinged flap. To the 9-inch by 5½-inch cross-piece are fixed the attachments for the lifting chain, and to the 9-inch by 7-inch cross-piece are bolted the hinges. The somewhat irregular shape of these is rendered necessary by the fact that the bridge must turn about its inner top corner.

The pivots of the hinges rest in little cast iron blocks, lined with brass, and with an iron top screwed on; the bearings of all the parts of the bridge are similar to these.

The lifting chains pass over cast iron wheels one foot in diameter, set in slits made in the spandrils of the entrance arch. I have no note as to how these are fixed. They may rest on bearings set in stone like those of the bridge itself, or may be enclosed in cast iron boxes, which could be slid into position from the outside complete; whichever it is is not of great importance; the point to bear in mind is that it should be possible to get at the bearings of these wheels to oil them, and to be able, if necessary, to remove the wheels without damaging the stonework. They may either be got at from behind, or a cross-shaped slit may be cut in the face of the spandril like a mediæval arrow slit, so that they may be reached from outside.

From these wheels the chains continue to the lifting gear, where they pass over two similar wheels, and are attached to the counterpoise. The axles of these wheels on one side rest on bearings set in the wall similar to the others, and on the other side they rest on an iron bar three inches deep, supported by the walls of the recess in which the gear is placed, and they are prolonged to meet one another over the roadway. In other words, a 2-inch square iron bar, sufficiently long to cross the roadway, and rest in bearings in the wall at either end, is made cylindrical for about one foot at each end; and at each end first rests in a bearing, next carries the wheel over which the chain passes, then bears on an iron bar, and then carries the sprocket wheel, to which a rope is fixed by which to work the gear.

The advantage of this connection between the gear on both sides of the bridge is, that the bridge, when lifted, rises evenly without any twisting; consequently the framing is not strained, the pivots work truly, with a minimum of friction, and the bridge can be worked from one side only. As a matter of fact, one man can raise it perfectly.

The sprocket wheels are 3 feet 5 inches in diameter; they are furnished with V shaped clips to prevent the rope slipping off them. The rope takes one complete turn round.

The power is communicated to the lifting chain by the friction between it and the wheel, which is found to be sufficient.

The counterpoise remains to be described. This consists, on each side, of a dozen hollow cylinders of cast-iron, $5\frac{1}{2}$ inches in exterior diameter, and $11\frac{1}{8}$ inches long. Through the centres of these cylinders pass rods, carried at each end by a chain of flat links. The lowest link is attached to eyebolts fixed in the wall. Below the counterpoise a small well is formed for it to sink into.

In order to prevent the bridge being raised by any unauthorised person, a hinged bar is so fixed that it can be laid across the counterpoise and padlocked at the other side, thus preventing its descent.

The advantage of the kind of counterpoise adopted, besides simplicity and easy manufacture, is that it can be adjusted to the proper weight by variations in the length only of the cylinders. The diameter of the cylinders having been fixed and the length necessary to give the proper weight calculated approximately, all the wrought iron work can be made, and on the completion of the bridge itself, when the weights are accurately known, the counterpoise cylinders can be rapidly cast with the proper longitudinal dimension.

Weight of Bridge.—It is not safe to estimate the weight of a bridge from tables of weight of materials; there are too many causes of error for one to be right in this way except by accident. The only way to get it correctly is to have every part of the bridge weighed in its finished state; all the iron work as it is completed; all the planks when planed; all the nails and screws; everything; it is easily done in the workshops, and from these weights the position of the centre of gravity and the tension on the lifting chains can be deduced.

It may be noted finally that the archway, which this bridge closed when raised, was 10 feet wide, 10 feet high in the centre, and 7 feet at the springing.

The bridge fitted into a recess 1 foot deep; 3 feet behind it were gates with a postern in them, and 10 feet back was the lifting gear set in recesses so as to leave its full width to the roadway.

Rolling Bridge.—The next form of bridge to be described is a rolling bridge.

In the shape of a plank put across a ditch and pulled back when it was desired to stop the communication, this was probably the earliest form of drawbridge.

Advantage.—It has a great advantage in not interfering with the work above the level of the roadway, so that in cases where the entrance does not pass through a vertical escarp wall there is no choice but to use some form of rolling bridge or a swing bridge, which is also independent of the work above the roadway, but is not in all ways convenient.

Disadvantages vary with the particular form used.—The forms of rolling bridge are rather numerous, and while this advantage is common to them all, the disadvantages vary with the types.

Rolling Bridges at Antwerp.—There are fine rolling bridges at the main entrances into Antwerp, very simple in idea but apparently only suited to large constructions and wet ditches.

A portion of the surface of the roadway forming the bridge is supported on a framework, which is provided with trucks, and moves on ten rails laid at the bottom of the ditch, so that it can be pulled back under the archway.

A space is provided for it to come into by carrying part of the roadway there on trucks in a similar manner, with the rails laid so that it can be hauled sideways into a recess, out of the way of the front portion.

One result of this arrangement is that there is either no escarp, or only a thin one at this point, but with a powerfully flanked wet ditch, this is of no consequence, and the simplicity and strength of the contrivance are of great value in a case such as this, where a main road has to be carried across the ditch.

It is easily moved by four men.

Rolling Bridge moved by a rack and pinion.—Another form of rolling bridge is one which is moved in and out by means of a pinion acting on a rack fixed underneath the bridge, the latter being kept horizontal by a counterpoise at the inner end.

Advantage.—It has the advantage of not requiring any particular form of escarp, either above or below it, so that it can be applied to batteries with sloping escarps, such as those with wet ditches.

Disadvantages.—The objections to it are, firstly, that it is found to be slow to work; secondly, that as it has to be rolled back under the roadway, a somewhat abrupt change of level is necessary where it goes underneath; thirdly, that the outer end of the bridge, being entirely unsupported while being run out, is liable to sag and not to arrive high enough to rest in its proper position on the counterscarp. This evil would be minimized by using wrought iron girders and not wood for the bridge.

Cams may be used to lift the outer end of the bridge when it arrives at the counterscarp, so as to give it a good bearing, but this addition of mechanism is objectionable.

Fort Regent Rolling Bridge (*Plate* XVIII.).—This form of bridge will usually be found rather troublesome, but as it possesses the advantage above named of not interfering with the escarp, the drawings and description of the rolling bridge at Fort Regent, Jersey, are reproduced from the paper by Lieut. Denison, R.E., in Vol. IV., *R.E. Professional Papers*, First or Quarto Series.

Fig. 1. shows the plan of the underside of the bridge: *aa* are beams of African oak, 12 inches square, forming the main timbers of the bridge; to the underside of these beams are spiked the iron rails *bb*, which rest upon the rollers *gg* fixed to the masonry upon the edge of the escarp; *cc* is a rack bolted to the iron bearers *dd*, which, being fixed to the two outside beams of the bridge, serve at the same time to connect and steady the whole framing; *ee* are trucks let into the two outside beams of the bridge at the inner end; these are shown on a larger scale in *Figs.* 4 and 5, where it will be seen that the same framing which carries the truck supports also a friction roller *f*, which, acting against the sides of the opening left in the masonry to receive the bridge, serves to keep it in its place, and to render its motion more easy. The hand-rail moves with the bridge, its motion being rendered easy by the rollers in the standards *pp*; when the bridge is withdrawn, the brow *x* (*Fig.* 2), which moves upon hinges, falls down over the opening in the escarp.

Fig. 2 is a section showing the ditch and the bridge as run out.

Fig. 3 is an end view of the bridge, showing the machinery by which it is worked.

Figs. 4 to 17 show, on a larger scale, the various parts of this machinery.

The width of the ditch is 17 feet 6 inches, and the whole length of the bridge is 32 feet 9 inches. The length from the inner end to the roller at the edge of the escarp is 14 feet 6 inches; and to counteract the tendency of the additional weight of the roadway of the bridge to sink the end below the rebate in the counterscarp (a circumstance which sometimes occurs even now after rain, when the plank of the roadway is saturated with water), 400lbs. of scrap-iron are bolted to the beams at the inner end as a counterpoise.

The clear width of the bridge is 9 feet 2 inches; it is covered with 3-inch oak planks.

The mode of working the bridge is very simple; the pinion *h* works in the rack *c*; the axis of this pinion, of 2½-inch iron, is carried into one of the bombproof casemates for the defence of the ditch, and there, as shown in *Fig.* 16, carries a toothed wheel. which is acted upon by another pinion; the force of one man acting upon the handle or winch of this pinion is quite sufficient to move the bridge.

Total weight of bridge, 6 tons 15 cwt. 3 qrs. 10 lbs.

Guthrie's Bridge (*Plate* XIX.).—The rolling bridge which is left to the last of that class is, taking it all together, the best of all forms of drawbridge. It is that invented by Mr. C. T. Guthrie. It, to a certain extent, partakes of the characteristics of an equilibrium bridge, as during the first part of the action of drawing it assumes various positions, the centre of gravity still moving in a horizontal line, but at the end the bridge is simply rolled in along the roadway.

The description is extracted from Mr. Guthrie's paper in Vol. XIII. of the *R.E. Professional Papers*, Second Series.

"The bridge is formed of two rolled or built wrought iron girders covered with planking, and supported at their centres by cast iron struts; these are suspended by links in such a manner that while the upper ends of the struts accompany the bridge in its motion, the lower ends travel nearly vertically against the escarp wall. Thus their centres of suspension, which are also their centres of gravity, descend in circular arcs, while their upper ends which support the bridge ascend in arcs of a certain curve. The weight of the struts is thus opposed to the weight of the bridge, and the position of their points of suspension, their angle of inclination and weight, and the form of the racers against which their lower ends travel, are such that they balance the weight of the bridge in every possible position. It follows from this that the force required to move the bridge is exceedingly small, being due only to the friction on the axles.

"The proper curve for the racers on which the lower ends of the struts move, and which are fixed against the escarp, can be found by drawing the bridge in various positions, and arranging the curve so that the relative vertical motions of the centres of the bridge and of the struts may be inversely proportional to their weights.

"The most convenient proportion to make the several parts of a bridge of this description, which may vary in length from 10 feet to 40 feet, is, perhaps, to give the struts an inclination of 30°, to make them half the weight of the bridge, and to cause their centre of gravity to descend, as the bridge is rolled back, twice the space the bridge itself has to ascend."

Advantages.—The principal advantages of this bridge are the ease

with which it is moved, one man being sufficient to do it, and the fact that it interferes with nothing above the level of the roadway, thus rendering it independent of the construction of the gateway, and of any walling above that level. It can also be run in and out with the gate closed. Where any architectural effect is required it is the best bridge to use.

Disadvantage.—The disadvantage is that it requires very careful construction and fitting, so that at many stations it would be impossible to make it.

Lithographed Details of Guthrie's Bridge.—A lithographed sheet of details of Guthrie's bridge for 14 feet span has been issued with Director of Works' Memorandum, No. 172, dated 18th January, 1870, with a specification, which renders it unnecessary here to describe the bridge in detail. It should, however, be observed that care must be given to the construction of the roadway on each side of this bridge, as there is a considerable thrust from its outer end, and a considerable stress on the ties that support the centre of the struts.

Equilibrium Bridges.—The third, or equilibrium, type of drawbridge is that in which the bridge itself is so moved that while its inclination varies, its centre of gravity moves in a horizontal line. It follows from this that when the bridge is drawn in the centre of gravity will be a little below the road level, and if the bridge be of uniform construction, half of it will be above the roadway and half below. Thus a bridge twice as long as an ordinary lifting bridge can be used.

Ardagh's Bridge (*Plate* XX.).—A description of a drawbridge of this nature, proposed by Lieut. Ardagh, R.E., will be found in Vol. XVII. of the *R.E. Professional Papers*, Second Series.

The principle of Ardagh's bridge is very simple; the bridge, of length equal to twice the height of the gateway, which it will cover when in, is supported at its outer end on a ledge, as usual, and is also suspended from a point intermediate between the centre of gravity and the inner end by rods fixed to the escarp above. The inner end, when in position, is secured by bolts so as not to drop when a weight comes on it, and when in motion is constrained to take the proper position by a curve cut in the escarp.

The length and position of the suspending rod are determined by the necessity for the bridge to be horizontal when down, and vertical when up, and for the corresponding positions of the centre of gravity to lie in the same horizontal line.

From this it follows that the length of the rod should be equal to the height above the roadway of the point of attachment of the rod to the escarp, added to the distance of the centre of gravity of the bridge from the point of attachment of the rod to the bridge.

This condition permits of a certain amount of latitude in the choice of dimensions. The simplest arrangement, perhaps, is when the point of attachment of the rod to the escarp is at the level of the end of the bridge when drawn in.

The curve on the escarp would be best found graphically. The bridge is drawn by pulling at the handrail, which is attached to it in a suitable manner. It has the advantage over an ordinary lifting bridge, that it requires no counterpoise, and that it can be conveniently made twice the span of a lifting bridge in a similar position; otherwise it has the defects of a lifting bridge.

A small bridge of this description has been set up at Newhaven Fort, and others elsewhere.

In Vol. XXI. of the *R.E. Professional Papers*, Second Series, will be found a description of a variation on this plan, by which the outer end of a bridge is made to drop instead of the inner end, the suspending chains going to the outer end, and the guiding curve being cut in the wall above the roadway. It was designed for use in a retrenchment inside a fort, with the intention that the enemy should not be able to prevent its being drawn in. It is referred to here on the chance that a drawbridge with such a motion might in some case be found desirable, though drawbridges should not be used in the interior of works.

Swing Bridges.—Swing bridges, though mechanically capable of use for long spans, are not suitable for large military bridges, on account of the space they take up, and the way in which they are necessarily exposed.

Advantages.—They are, however, sometimes convenient, as they do not interfere with the escarp above or below the roadway, nor with more than a small length of the roadway itself.

They can thus be used in cases where a rolling bridge cannot on account of the form of the entrance, and also for spans too great for an ordinary lifting bridge; thus they appear suitable in some cases for foot bridges, when considerations of strength do not necessitate intermediate piers of support.

A very neat form of swing bridge, for foot passengers only, was designed and put up at one of the batteries at Inchkeith in the Firth of Forth, by Major Locock, R.E., to whom I am indebted for the loan of the drawings.

Inchkeith Swing Bridge (*Plate* XXI.).—It is four feet wide, with a clear span of 15 feet, and is calculated to carry safely 6 cwt. per foot run, so that projectiles for 10-inch guns can be taken across it.

The nature of the construction will be seen from the drawing.

The total length of the bridge is 22 feet $7\frac{1}{2}$ inches, and it works on a pivot and racer, the pivot being 5 feet $1\frac{1}{2}$ inches from the inner end, and the weight of the longer end being balanced by a cast-iron counterweight. It is strengthened on each side by a vertical strut, and two tie rods. The bridge is swung to and fro without any mechanism, but simply by pushing. When it is in position across the ditch, the weight of the outer end is taken by an eccentric bar raised by a couple of levers. These levers when up form standards for the side chains, which, when hooked on to them, prevent their being lowered.

The fittings are mostly of cast-iron, which can easily be procured in this country, though not in some of our foreign stations; the general arrangements of the bridge could, however, be preserved if other materials were used. It is a very convenient form of small foot bridge, easily set up and worked.

It obviously cannot be protected from projectiles fired directly at it, but can be used, as here, in retired places not exposed to shot.

10.—EFFECT OF THE NATURE OF SOIL ON DESIGN.

Effect of the Nature of Earth or Rock on Design.—The details of the design for a fort should be influenced by the nature of the ground on which it is to be built, and it is necessary to inspect the site carefully before beginning the plans. Every different earth or rock has its own advantages and disadvantages—except the clay called blue slipper, which has no advantages that I am aware of—and each requires its own treatment; it is plain, for instance, that a hill of earth can be cut about much more easily than a hill of hard rock, and therefore in the latter case, one must be much more guided by the accidents of the ground than in the former.

Rocky Sites.—If the site be rocky, the first thing to do is to see how near the rock comes to the surface, as it is usually covered with soil of more or less depth. It will be advisable to remove this soil, and to put it where it will not be disturbed during the progress of the works, so that it may be used for covering the parapets and glacis, with a view to encourage vegetation and to prevent the splinters flying when struck by shot or shell.

The rock should be carefully examined, and the opinions of people who know the local stone taken, as to whether it is fit for ashlar, rubble, or concrete, or whether it is useless for all these purposes, as it would be if, for instance, it were very light and shaley.

Ashlar.—If the stone be fit for ashlar, cut stone may be made use of about the casemate fronts, entrances, and bombproofs, and in any other places where it may not be exposed to injury, and the opportunity may be taken to give the work a little more finish than is usual.

Rubble.—If it must be used as rubble, a different style must, of course, be adopted. Rubble masonry looks very well in a fort; it appears to harmonize with the character of the work more than any other style of construction, and there is of course economy in using the stone just as it comes from the quarry, so that it is preferable to use stone as rubble for the greater part of the work, even if it were capable of being dressed as ashlar.

A certain amount of brick or ashlar will be required for use where fine work is necessary.

Concrete.—Most hard rocks can be used as concrete, and this is perhaps the most generally serviceable material for use in fortification. Its quality can be varied to suit different circumstances, and if carefully mixed it can be applied to almost any purpose, even in places which will get such hard wear as steps. It is not, however, advisable to try any but simple forms with it, or the expense of the moulds becomes too great to make it worth while. It is difficult to give buildings made of it a good appearance, but a solid and simple style of construction is the best.

It may be mentioned here that a good effect has been obtained with some casemates built at Chatham, which are faced with concrete made with pounded granite. By scrubbing the surface the coating of cement has been removed, and the glitter of the granite made visible.

Arches in concrete may be made with polygonal soffits, thus simplifying the centering and making it easier to manage the groining.

Poor Rock.—If the rock is useless for building purposes it yet may save some trouble in the way of revetments, as, for instance, in the case of chalk, where the escarps only want facing to secure them

from the effects of weather. Here the casemates, &c., must be made of the local building material, whatever that may be, if it is sufficiently suitable.

Sites on Earth.—Earth may be either gravelly, sandy, or clayey.

Gravel.—If gravelly it will provide material for concrete. If used for the parapet it will be necessary to cover the parapet with loam or sand to prevent stones flying.

Sand and Clay.—Sand and clay are useless for building purposes unless the latter is of a quality which will admit of burning into brick. As these materials will not stand permanently at a steep angle, easy slopes should be used in the work; not more than 1 in $1\frac{1}{2}$ for clay, and 1 in 2 for sand. It must not be forgotten that sand is the best material for parapets, while clay is the worst. The latter material may, perhaps, be used for the hearting of a parapet, but from three to five feet of the exterior should be sand, or as light a loam as may be procurable.

Effect of the Soil on the Design.—Besides affecting the details of construction, the nature of the ground will affect the design of the work. For instance, in a hard rock it is best to get all the material if possible out of the ditch; it will cost very little more than quarrying elsewhere on the site, and the strength of the work will be added to. On an earth site every increase to the depth of the ditch involves an increase in the thickness of the escarp and counterscarp walls if such be used, and more earth moved in order to get them in, even if they be not actually increased in height. In such a case, therefore, it is best to settle on a good form of ditch, and to get from another place any earth that may be required to complete the parapets.

An earth site lends itself to the modern form of work, with long easy slopes, whereas on rock it would usually be best to adhere to ditches with vertical sides.

In a rocky site where mining is not likely to be used by the enemy, counterscarp galleries may be used to flank the ditches.

It is not necessary to take such pains to conceal a natural rock escarp as a built one.

A work on a rocky site where the interior slopes can be revetted, and where the stuff will stand at a steep angle, need not cover quite so much ground as one on a sandy or clayey soil.

When a fort stands on a soft rock which can easily be cut and yet will stand of itself, underground galleries of communication may be freely used, as it is easy to make them.

11.—HINTS ON DESIGN.

The following pages contain some hints on how to set about designing a fort. They must necessarily be rather desultory, as of course there are all sorts of variations in the circumstances under which the work is done, and moreover nearly every one has his own way of setting to work and will not follow mine. Still a few remarks may be useful even if they only serve to call to mind the things that have to be attended to.

Nature of Map Available.—It may be assumed that the officer making the design is possessed of a general map of the country, like the one inch to a mile ordnance survey sheets, but of more doubtful authority. Out of England such will be the usual basis.

Charts.—For a coast fortress, such as ours almost invariably are, a chart must of course be used in order to lay out the coast defence, and it may also be useful for the landworks, but the hill shading on an Admiralty chart must never be trusted; it does not aim at giving an exact representation of the ground, but only at indicating its appearance from the sea. The views on Admiralty charts are, however, always correct as far as I have been able to judge.

Study of the Map.—After walking, riding, or driving about the country till one has learnt its features, one will know the qualities of the map and how far it is to be depended on, whether its roads are right, whether there are any peculiarities in its hill shading that have to be remembered in order to understand what sort of ground is signified by it, whether its coast line is right, and so on; also whether many changes have been made since it was printed. In short, one must learn to read the map and to know where it is incorrect or wanting, for without it it would be almost impossible to assign the proper relative value to the various works and parts of works. The attack and defence cover such large areas now-a-days that it is only with the aid of a map, on not too large a scale, that it is possible to bring before the mind simultaneously all the points bearing on the selection of the sites for works.

Choice of Sites.—Having chosen the positions for the works on the map, go out on to the ground again and examine these points with more minuteness, so as to decide the sites as far as can be done at this stage. Sometimes it is necessary to wait for a more exact survey before it is possible to settle the claims of two or three rival hill tops, but usually most of the sites will reveal themselves at this

stage of the proceedings, and their relative importance and the general qualities of the works to be built will also have become apparent, being decided by tactical considerations.

Nature of Works.—It will be possible to decide whether a fort must be self-contained and able to resist the enemy without much help from collateral works, or whether it shall be a mere satellite to some dominating position; whether it shall be most powerful for front or flank fire; whether it is likely to have an attack carried on against it through all its stages, or whether it will only be shelled from a distance.

In fact it will be possible roughly to design the works in one's own mind, and to know approximately their sizes and positions.

Survey of Sites.—This is a necessary prelude to the next step, which is to get the sites surveyed.

Scale of Survey.—40 feet to 1 inch.—Now as to the scale on which this is to be done, I have found practically that a scale of 40 feet to 1 inch, contoured at 5 feet intervals, is the most convenient for the general design of a work, and the one to which the plan of all the ground likely to be covered by the fort and its glacis should be made. It is sufficiently large to get accuracy for such things as casemates and gun emplacements, and the slopes of parapets, while it is not large enough to drive one into showing details which are not wanted in the first stages of a design. Some officers prefer using a scale of 30 feet to 1 inch, which, being a little larger, is more convenient for details.

It is of importance not to use too small a scale, or one is liable to be led into difficulties at a later stage of affairs. Two or three little details—slopes, flights of steps, or something of that sort, which seemed to fit in very nicely on the small scale, will often prove to be much larger than was expected when expanded to a size sufficient to show the full dimensions of all their component parts, so that they will not fit into the space originally allotted to them, but make a fresh arrangement necessary. And it is surprising how small an alteration will sometimes affect the design of a whole fort; widening a passage, for instance, may shift a set of casemates, which may affect the magazine service and so modify the parapet, and possibly, at last, even the outline of the fort.

Scales for Details.—Another advantage of the scale of 40 feet to 1 inch is that it is easy to reduce to it details drawn on the scales of 10 feet to 1 inch, or of 4 feet to 1 inch.

Scale of General Survey $\frac{1}{2500}$.—Besides the 40 feet to 1 inch scale of the immediate site of the work, this and some of the ground around should be done to the scale of $\frac{1}{2500}$, contoured at 10 feet intervals. A plan on this scale is the best for making the first rough sketch of the design on. It should include the ground between the works and for some little distance in front and in rear of them, so as to embrace the positions for the auxiliary batteries of the defence and the near approaches of the enemy. It is a convenient scale for showing the works in their relation to one another.

These scales of $\frac{1}{2500}$ and 40 feet to 1 inch, are sufficient for the design, for although of course it will be found necessary to draw some details on a larger scale, in order to get exact dimensions, yet 40 feet to 1 inch gives a plan sufficiently large for deciding on the merits of the project.

Scale for approved designs.—10 *feet to* 1 *inch.*—As soon as the design has been approved and is to be carried out, drawings on a large scale become necessary—10 feet to 1 inch for general plans, and 4 feet to 1 inch for details, will be found convenient. It is well worth while drawing the whole fort, as it is laid out, on the scale of 10 feet to 1 inch and to contour it at one foot intervals, for on that scale every intersection of slopes and every turn in the whole plan can be shown, and the drawing forms a capital check on all subsequent work.

In fact the fort should be laid out on the ground, and on the plan of 10 feet to 1 inch at the same time; one can then be sure that as the drawing is finished, so the fort can be.

Permanent marks for laying out.—This plan will also enable one to see where permanent marks can be fixed, showing the main laying out lines, so that they shall not be lost by being dug up or covered over, and so that reference can be made to them in the progress of the work, and in making the record drawings.

Study of the Ground during the Survey.—While the survey is going on there will be an opportunity of examining the ground, so as to know its form thoroughly, and also of finding out the quality of the soil, whether clay, sand, or anything else, the depth to the rock if there be any, its quality, and so on, so that the designs of the new fort may be properly suited to the character of the material with which it will be built. Also, of finding out what classes of workmen are obtainable, unskilled or skilled, and of the latter, whether many, and in what trades; also, whether it will pay to employ machinery as all this has an influence on the design.

It will also be possible to find out whether, before beginning work

any special arrangement will have to be made for water supply, for repair of roads, for the supply and storage of materials, for sheltering the workmen, for an office, and numerous other points which will insist on being attended to.

Some time during the progress of these preliminary operations it will be necessary to make arrangements for the purchase of the land required.

No more need be said about that, than that one must have some idea of the sort of work that is about to be erected, in order that enough land may be included to contain it, with its glacis and approaches. If land is cheap—if land ever is cheap that is sold to Government—it is advisable to hold a good deal round the work, in order to prevent its being blocked up by buildings.

Actual Design of the Work.—The actual designing of the work is partly a matter of trial and error; several rough sketches will have to be made before the fort gets into shape, and indeed it may be necessary to make drawings to scale, in order to settle various points about the dimensions. Do not be afraid of making plenty of drawings; it is easier and better to alter plans than to alter a fort once built.

Commencing the Design of a Land Work.—Position of Crest Line.—In sketching out a land work it will be found that the first thing to do is to fix approximately the position of the crest line of the parapet, so that the near slopes of the hill may be conveniently swept. This crest line will usually be from 10 to 15 feet above the level of the ground, the height depending partly on the nature of the rampart, whether solid or casemated, partly on the amount of cover desired, partly on the slope down which it is necessary to fire.

It may be that the position of the crest line determined thus, will indicate that the ground should be in whole or in part taken up with a continuous line. This is the case, for instance, in Malta, where it is necessary to occupy Dueira Hill with a continuous line nearly a mile long, there being no single position on the hill from which the whole of the slopes can be seen.

Inclination of Superior Slope.—The inclination of the superior slope, and of the glacis, will partly depend on the form of the ground, but it should not be steeper than $\frac{1}{7}$ if it can be avoided.

Arrangement of the Guns.—Then settle the arrangement and number of the guns. If any are mounted in the fort they will take the chief place, and the plan must be made to suit their arcs of fire, their service, and their security.

The guns in a fort may not be often used, but when they are used almost everything depends on them; at the beginning of a siege nothing besides artillery fire can touch the enemy, and there may be no other guns mounted but those in the forts; at the end of a siege the enemy's approaches can hardly be stopped by anything but artillery, and the guns in the fort attacked must be worked.

Filling in Details.—Having settled the position of the guns, the nature of the fort is approximately determined, and then comes the business of fitting in the casemates, the communications, the magazines, the ammunition service, and the flanks to the ditches; with regard to which I can give no hints; it is a matter of packing and arranging; a good many alterations are certain to be required.

After this the glacis should be drawn.

Design of a Coast Battery.—In order to keep the subject of design together, I here anticipate some details treated of in the following sections of this book. With a coast work the mounting of the guns is the *raison d'être* of the whole matter, and their lines of fire must be carefully considered.

Not too much consideration to be given to the ground.—And in this case it is well not to be too much influenced by the conformation of the ground around the site of the work in deciding on the positions and lines of fire of the guns.

Some consideration must, of course, be given to it, so that, for instance, the fort proposed may not be too large for the site which it is to occupy; but while bearing in mind the general nature of the position, the number of guns available, and the most suitable mode of mounting, still the best way of beginning the design is to lay down on the chart the arcs of fire which it would be most advantageous to get; then sketch out the sort of battery that would be required, and then see if it can be applied to the site. If it cannot, it may be possible by throwing one part back, or another forward, by altering the intervals between the guns, or by changing the mode of mounting, to attain the desired result.

Arrangement of the various parts.—Working out the design of a coast battery is to a great extent a matter of packing, owing to there being so many fixed dimensions about the emplacements; the chief things to attend to are concealment from view, the avoidance of exposure to enfilade or reverse fire, and convenience of ammunition service.

It is often difficult to protect a barbette battery from enfilade or

reverse fire, and all that can be done is to introduce large traverses and parados.

Casemates can either be protected by parados or can have arches built against the backs of the casemates; if the latter, care must be taken not to exclude the light too much, and not to impede the movement of air, or the blast of the guns may cause injury to the casemate fittings.

If it can be managed, gun casemates should be so arranged that a shot entering one of the ports would not be able to enfilade a line of guns. The chance of its happening is perhaps not great, and it is not always possible to guard against it; luckily, the guns make good traverses themselves. In a large casemated battery the best way would be to arrange the guns in groups, with large masses of earth and masonry separating them.

Ammunition Service.—In arranging the ammunition service the best plan is to mark positions for the lifts or issue hatches where they would be most convenient for the service of the guns, and then to endeavour to arrange the magazines so as to get them in these positions, or as near to them as possible.

In the ammunition stores the lifts should be situated conveniently for access, and not far from the store from which the ammunition is drawn. The winch should be placed on that side which is away from the direction of the service, so that the men working it may not be in the way of those bringing up the ammunition; and the lighting should be so arranged that the men may not stand in their own light when adjusting the shell clip to the shell, or putting the cartridge into the cage at the foot of the lift.

Drawing the Plans of a Coast Battery.—In making the drawings for a coast battery it will be found best to begin by laying down the pivots of the guns, and to refer all points on the gun floor to them. Then having obtained the exact positions of the lifts, make them the points of reference for the ammunition stores in the basement. This will ensure the agreement of the upper and under plans.

In drawing the sections the top surface of the racer is the level to which all the heights about the work must conform.

Land Works.—Returning to land works, the last things to do, which should never be omitted, are to calculate the deblai and remblai, and to make an approximate estimate of the cost.

With a little practice both these can be done in sufficient detail in a day's work, but this is not likely to be the case at the first attempt.

Deblai and Remblai.—The balancing of the deblai and remblai should be done approximately as the design progresses, by adjusting the height of the crest above the natural ground. This is a matter of judgment, but at the best can hardly be quite right except by accident. A calculation must be finally made; it need not be very minute as there are many disturbing causes in practice, but it will require repeating once or twice with altered levels till the correct one is found.

It must be remembered that an increase of size takes place in disturbed soil, vaying from $\frac{1}{13}$ in sand to $\frac{1}{3}$ in hard rock, and the proper allowance to be made must be ascertained before calculating the deblai and remblai for any particular work.

While it is always desirable to balance the deblai and remblai for economical reasons, yet defensive qualities should not be sacrificed to this. It may be found necessary in some cases to remove part of the deblai from the site in order that the work may not be unduly raised and conspicuous.

Approximate Estimate.—The approximate estimate, which may be made by cubing out the earthworks, excavations, buildings, etc., and allowing sums for tanks, entrances, roads of approach, preparing the ground, etc., is also very necessary. The cube prices used will of course vary with the locality.

Without being absolutely accurate it should give an idea of the cost of the work, so that it may be seen if it is in proportion to the value of the position in which it is to be placed, and it will also reveal any extravagances in the design, or injudicious modes of construction, so that they may be amended.

This is the finish of making a design for a work; the next step after its approval is the practical construction.

Construction of the Work.—No Lump-sum Contract.—And with regard to that, one or two points may be mentioned specially appertaining to fortification. One is, never make a lump-sum contract if it can be helped. The art of fortification will be advancing while the work is being built, and it is not good to be hindered by a lump-sum contract from making improvements.

Way for bringing in the Guns.—The other refers more especially to coast batteries, and is that a way should be left for bringing the heavy guns into the fort. It is usually convenient to leave a cut in the parapet, and part of the ditch unexcavated till the guns are inside. It would, of course, be convenient to get the guns in before the work is finished, but this can rarely be managed. It is best to arrange on the supposition that the guns will not come till the work is practically finished.

12.—PREPARATIONS AGAINST ATTACK.

Preparations against Attack.—The opportunity may here be taken of saying a few words on the desirability, indeed almost the necessity, there is of arranging in peace time for the execution of those works in a fortress which would have to be carried out on the outbreak of war.

The design and construction of the temporary redoubts and batteries is only a small part of the work to be done.

Besides that, it must be decided what is required to put the permanent works into a state of preparation for use, such as building bombproofs and traverses, mounting guns, and arranging for the accommodation and supply of the garrison.

Besides that again, there will be camping grounds to prepare, roads to make, ground to clear, hospital buildings and store-houses to construct.

Lists of the materials required, such as can be got in the neighbourhood, should be prepared, and it should be known where they can be procured and how to get them to the spots where they are wanted.

The numbers required for the working parties should be settled, and the local employers of labour should be consulted with as to where men can be found.

It must be remembered that, besides the Engineer work that has to be done, the Artillery will be moving guns and ammunition; the Supply departments getting and shifting stores; and the civil population either leaving the place or making preparations to endure the discomforts and dangers that may be before them. Unless the requirements of the various departments are settled beforehand, their simultaneous demands for men, materials, and transport are likely to lead to a block in everything just at the time when it is desirable that all should proceed as rapidly as possible.

I have myself endeavoured to lay down the requirements of a small fortress with which I was connected, so that the necessary steps might be taken which would enable it to be put in a state of defence with the least possible delay. This preliminary statement of the case covered 27 folio pages of print. It would certainly take several months before the whole matter could be completed. This was a comparatively easy case, but in many the work would be numerous, and putting off doing it to the last minute is a likely way to produce a great disaster.

Permanent Fortification For English Engineers

LEWIS

Chapter 3

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Instructions have now been issued to general officers commanding for drawing up schemes of defence for fortresses, calling on them to prepare complete projects of all that is required to put them in a state of readiness against attack. These, when completed, will require constant revision in their details to keep them up to the requirements of the day, and periodically a general overhaul of the whole system will be necessary to meet the introduction of new weapons or large changes in tactics.

Many useful hints on this matter will be found in *The Organization of the Auxiliary Services in a Besieged Fortress*, by Major-General Von Kamptz, of the Prussian Artillery, of which an abridgment by Capt. Gore Booth, R.E., will be found in the *Journal of the United Service Institution*, Vol. XXIII., 1879.

CHAPTER III.

THE STORAGE OF AMMUNITION.

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1. Magazines: Barrels; Cases and Cylinders; Skidding and other Fittings.—2. Shifting Lobby.—3. Lighting.—4. Shell Stores.—5. Lifts.—6. Recesses.—7. Shell and Cartridge Filling Rooms.—8. Adjuncts to Store Magazines.—9. Nomenclature and Lettering.—10. Dampness in Magazines.—11. Lightning Conductors.

1.—MAGAZINES.

Definitions.—The word "magazine" besides being the general term for any place where ammunition is stored, is also more particularly applied to a place where gunpowder is kept loose in barrels or cases. The place where it is stored made up into cartridges, is called a "Cartridge Store," and, owing to the much increased proportion of ammunition that is now kept in a made-up form, the term "Expense Cartridge Store" has entirely superseded "Expense Magazine."

The largest reserve magazines in a work are called either "Main Magazines" or "Main Cartridge Stores," according to the nature of their contents; the former usually in land works, the latter in coast batteries, where all the cartridges are kept "made up" and all the shells ready filled, and where there is, therefore, no powder in barrels. Where cartridge and shell stores are combined together in one building, they are collectively spoken of as "Ammunition Stores."

"Store Magazines" are for reserve gunpowder, whether in barrels, or made up into cartridges.

Store Magazines.—Main Magazines.—Cartridge Stores.—Expense Cartridge Stores.—For convenience of consideration, magazines may be divided into four classes: store magazines, main magazines in forts, large cartridge stores in coast batteries, and expense cartridge stores. There are all sorts of intermediate sizes, but these may be taken as typical. It is proposed first to describe the general arrangements, and afterwards to discuss the question of how to keep magazines dry, which is very important.

There are three things to consider in the arrangements of a magazine: the magazine chamber, the entrance with the shifting accommodation, and the lighting.

MAGAZINE CHAMBER.

The magazine chamber contains the gunpowder either in barrels, metal lined cases, zinc cylinders, or brass cylinders.

Gunpowder is stored loose in barrels; in metal-lined cases it is either loose, or made up into cartridges for medium and light guns; zinc cylinders contain the cartridges for heavy guns for land service; brass cylinders are used by the navy.

Size of Barrels and Cases.—A barrel is 1 foot 5½ inches in diameter in the widest part, 1 foot 3½ inches at the ends, and 1 foot 9 inches long. A metal-lined case is 17 inches by 17 inches by 21½ inches.

Small Arm Ammunition.—Small arm ammunition, containing its own means of ignition, is not to be stored in the same chamber with gunpowder. See *Equipment Regulations*, 1881, Appendix; also *Regulations for Ordnance Store Department.*

This regulation embraces the ammunition for machine guns, and for the quick-firing 6-pounder and 3-pounder, and any other that may be adopted into the land service, if it contains its own means of ignition. It is, however, in contemplation to make the caps of the cartridges of Q.F. guns removable, so as to get over this difficulty of storage. A place will have to be provided for the caps.

Small arm ammunition is packed in quarter barrels, or in small arm ammunition boxes. A quarter barrel is 11·6 inches diameter, 14·2 inches high, weight full 83 lbs.

A small arm ammunition box is 21¾ inches by 6·9 inches by [illegible] inches over all, and weighs when full 79 lbs. 8 ozs. There is a cleat and rope handle at each end.

No more quarter barrels will be made.

The ammunition for quick-firing guns is packed in boxes. Their dimensions and capacity are as follows:—

For Hotchkiss 3-pounder Q.F. gun, containing 16 rounds—

Length over all	14·75 inches.
Width	12·375 ,,
Height	22·75 ,,
Weight, filled, about	125 lbs.

For Hotchkiss 6-pounder Q.F. gun, containing 11 rounds—

Length over all	16·25 inches.
Width	9·9 ,,
Height	21·15 ,,

It is to be noted that these boxes must always be stored standing, either on one end, or on their broadest side, and with a narrow side to the front, as rope handles are fixed on the narrow sides.

By the Regulations, they are to be stored on their ends, not more than four tiers high, and with 2-inch battens under the lowest tier.

Each round for the 4·7-inch Q.F. gun is made up with the powder in a brass case; the projectile is separate. Each charge is at present six inches in diameter over the base flange, and about 15 inches long, but the dimensions are not finally settled.

For further information see the *Treatise on Ammunition.*

The barrels and metal-lined cases are both stored on the same form of "skidding," which is a name given to the wooden framing on which they rest. Zinc cylinders do not require skidding.

As the dimensions and the arrangements of a magazine depend on the skidding, and the mode in which the powder is stored on it, it is necessary first to describe it.

Skidding (*Plate* XXII.).—Skidding is specially adapted for storing powder barrels. It consists essentially of two pieces of wood side by side, 13 inches apart, and usually 4 inches wide by 3 inches deep. These support the barrels conveniently resting on their ends. The barrels should be kept from rolling and from touching the walls by vertical pieces, 6 inches by 4 inches in section, and if the magazine is a long one, the skidding should be separated into bays by vertical pieces which may be 4 inches by 6 or 8 inches. The ends of the barrels are usually separated by a distance of 6 inches, but they are sometimes allowed to touch.

Above the fifth row of barrels, *i.e.*, at a height of, say 7 feet in the clear above the lower horizontal bars of wood (five rows of barrels being 6 feet 6 inches high), horizontal transoms, 4 inches wide by

6 inches deep, should be introduced, on which barrels can be piled up higher. They should not be stacked within two feet of the roof.

It should be observed that it is not considered advisable to carry the vertical pieces into the arch over head; they should be supported by struts abutting against the side and end walls.

The skidding should be separated from the side walls by a space of at least 6 inches. In large magazines this should be increased to two feet, so that the barrels may be inspected.

These regulations, together with some others, will be found laid down in I.G.F.'s Memorandum, No. 189, dated 1st November, 1871; also in I.G.F.'s Circular, No. 203, dated 20th June, 1873, which still holds good as far as regards the storage of barrels.

It will be seen there that the only regulation concerning the height to which barrels may be stored, is the one prescribing a horizontal transom above the fifth row. Barrels have been stored without injury to a height of 11 rows. In a small magazine it is better not to introduce a horizontal transom which might cause a loss of accommodation.

Lengths of Skidding.—The length of the blocks of skidding is regulated by the strength required by the upper horizontal transoms. A length of 13 feet 3 inches to take nine barrels side by side is best. The transoms will then bear barrels containing pebble powder, piled four high, with a sufficient factor of safety. A length of 14 feet 8 inches to take 10 barrels should not be exceeded. A barrel of P^2 weighs 125 lbs., in addition to 31 lbs. the weight of the barrel itself. In those expense cartridge stores for medium guns, in which the ammunition for more than one nature of gun is stored, it will be found convenient to separate the various natures of ammunition by vertical divisions.

Crane.—Plate XXII.—In large magazines a traveller or crane of some nature is necessary to raise barrels to the upper rows.

A simple form of crane has been used with success at Fleetwood, but has not met with approval elsewhere. It consists of a jib working in a frame which travels in grooves cut in two baulks, one above the other, running the length of the magazine. It is moved from place to place by simply pulling at the rope by which the barrels are hoisted.

Another arrangement, which can moreover be used when there is not sufficient height for the crane, consists of a small traveller, running on horizontal bars of wood attached to the uprights of the skidding. It is formed by a copper bar, $1\frac{1}{2}$ inch diameter, supported on two small flanged wheels at each end, 6 inches in diameter and 14 inches apart from centre to centre. On the bar runs a small pulley, to which is suspended another pulley for the rope by which the barrels are lifted. The pulley can travel from side to side with the barrel suspended to it, and the whole forms, in fact, a miniature gantry. The copper bar may be 5 feet long.

Wall Battens.—Plate XXII.—Wall battening has to be used in store magazines to prevent grit being kocked off the walls, which it should cover. It may be made of light 3-inch by $\frac{3}{4}$-inch stuff, and should have an air-space behind the battens.

Floors.—The floors of all magazines should invariably be made with concrete, the surface being either floated with pure cement, or asphalted. The ordinary wooden floors carried on joists, which have been extensively used in our older works, are liable to suffer from dry rot, thus becoming dangerous and involving expensive repairs. The advantage of having a wooden surface for moving ammunition on is obtained by the use of batten flooring.

Batten Flooring.—The batten flooring which is used for covering the cement or asphalte floors of magazines, has been made of two patterns; the lighter one having been used in cases where no very heavy weights had to be moved over it.

The stronger one is, however, more generally serviceable. It was made to suit the cartridge stores of heavy guns and for shell stores.

A leading idea in designing the batten flooring was, that it should be guarded as far as possible against the effects of damp; consequently spaces are left, so that the air may have free access to the woodwork, and what is specially important, the flooring is made in sections of such a size that they can be conveniently taken up and carried out of the magazine to air; and they should be so taken out whenever the magazine is not in use.

The pattern of heavy batten flooring used in Indian works consists simply of $2\frac{1}{2}$-inch boards laid side by side on the concrete floor. It appears simple and efficient.

Plate XXIII.—The lighter form of flooring consists of 6-inch battens $\frac{3}{4}$ inch thick, laid on 3-inch diagonal battens also $\frac{3}{4}$ inch thick; the upper battens are set with a slight clearance, the lower ones are 6 inches apart.

There are two $1\frac{1}{4}$-inch brass screws at each crossing.

There are a couple of hand holes in each section of flooring for convenience in raising it, and a riband $1\frac{1}{2}$ inch by 1 inch is fixed on the side next the wall.

Plate XXVII.—The stronger form of flooring is made of battens

3 inches wide and $1\frac{7}{8}$ inch deep, with intervals of $\frac{3}{8}$ inch between each.

The ends are screwed to pieces 4 inches by $\frac{7}{8}$ inch, with $1\frac{3}{4}$-inch brass screws, and a riband, 2 inches by $1\frac{3}{4}$ inch, is fixed on the side next the wall.

Batten flooring should be made of such a size that it may be clear of the walls all round by about 1 inch.

The under sides of the battens should be tarred, to preserve them from damp.

Batten flooring is used in all powder magazines, and in any cartridge stores which might contain powder not made up into cartridges, including the passages up to the barriers. When used with skidding it is placed in the passages between the bays. In other cases it covers the whole floor. By I.G.F.'s Circular 544, 24th January, 1888, it is not to be used in chambers and passages where cartridges only are stored.

When asphalte floors are covered with cork composition to prevent condensation, it will be necessary to employ batten flooring to protect the cork from being rubbed off.

Magazine Chamber.—Having settled the details of the skidding and other fittings, we may now return to the description of the magazine chamber itself.

Store Magazine.—Plate XXII.—The most convenient sectional dimensions for a large store magazine will be found to be 20 feet wide by 16 feet high to the crown of the arch, and 10 feet 3 inches to the springing.

The width allows the barrels to be stored in two blocks, each three rows wide, with access afforded to them on each side by a passage 4 feet 3 inches wide down the centre, and others 2 feet 3 inches wide down the sides, the ends of the barrels being in contact.

The height permits nine rows to be stored, with the horizontal transom over the fifth row, and the rise of the arch gives room for the travelling crane before described or for the gantry.

The length should suit some definite number of barrels, not leaving too much play, the dimensions of the blocks of skidding being regulated by the considerations of strength given in a former paragraph.

A way must of course be left round the ends of the skidding. In magazines which have a central passage running across the chambers, a way may be left through the skidding at the floor level, the storage being continuous on the upper transoms.

Skidding of Store Magazines.—As the charges of heavy guns will in future be issued made-up, and packed in zinc or brass cylinders, some portions of store magazines should be made suitable to receive them. This may be done by filling in between the floor skids with batten flooring, blocked up so as to make a level surface The upper tiers of the skidding would still be suitable for the storage of barrels. (See I.G.F.'s Circular 504, dated 11th February, 1887.)

In some few places a large case for storing prism powder may be met with. It is 32·9 inches by 12 inches by 11·25 inches, and contains 200 lbs. of powder. The traveller in the magazine containing it would probably have to be modified and strengthened. Some form of gantry would most likely be the best thing to use.

Size of Store Magazine Buildings.—As a rule, store magazines should not be constructed for more than 8,000 barrels each, *i.e.*, in each separate building. A store magazine establishment may contain several of these buildings.

Position of Store Magazines.—Store magazines should, where possible, be constructed on sites remote from residences and populations, and from embankments for preventing inundations, as well as from property of value which might be injured by explosion. The site should also afford easy communication to and from it by water.

Fort Magazine.—Main magazines in forts are similar in arrangement to store magazines, but are more varied in shape to suit the exigencies of defence.

The skidding must be arranged according to circumstances, the design having been suited to it as far as possible.

Particular attention should be paid to securing an easy issue of powder from a fort magazine, in order that the expense magazines may be rapidly filled up from it during a siege.

The passages should be broad, and several issue hatches or other means of passing out ammunition should be provided.

Fitting up Fort Magazines.—While every magazine should be arranged so as to be capable of taking skidding, it is not always desirable to supply either it or the battens to fort magazines. They may never be used in peace time, and if the skidding and battens be in them, the wood might perish from damp, or they may never be required for powder barrels at all, in which case the woodwork is not necessary.

The best course to adopt is to have the woodwork shaped, if ever likely to be wanted, and stored in some dry place, ready to frame together.

If a magazine has plenty of floor space, a number of cases can be stored without any skidding at all, merely on planks laid down on the floor. In many English works this is sufficient, the storage accommodation being ample.

Small Cartridge Store.—Plate XXIII.—Convenient widths for small fort magazines and cartridge stores are 8 feet, 11 feet, and 13 feet; 8 feet allows of two rows of skidding, and a 3-foot 3-inch passage; 11 feet of three rows, and a 4-foot passage; 13 feet of four rows, and a 3-foot 9-inch passage; in all cases with six inches between the ends of the barrels.

When more rows than this are used, that is where three rows come together, there should be a passage on both sides of the block of skidding. Three rows on one side of the store and two on the other, with a 4-foot passage in the centre, and a 2-foot passage on one side, would require a width of 17 feet, or of 15 feet 6 inches, according as the ends of the barrels are separated or not, and as we have seen in the store magazine, three rows on both sides require a width of 20 feet.

From the point of view of economy of space it does not much matter which arrangement is used, except the 8-foot width, which is only suited to small expense cartridge stores.

Fittings for Magazines.—Brass or copper fittings, screws, nails, &c., should invariably be used in magazines where the powder is stored in barrels, and also, according to present regulations, in cartridge stores, where it is in zinc cylinders, unless very special cases may render the use of iron necessary. Iron should, if possible, be galvanized. This does not refer to iron used in construction as, for instance, for roof girders, to which there is no objection; but iron columns should be boxed in with wood.

Locks.—Brass locks suitable for magazines are specially made, both rim and mortice, 6-inch and 4-inch, with brass drop handles; and also padlocks. Magazine locks should invariably be made in sets, governed by a master key for each district, with a general master key over the whole. Sets of locks can be obtained from Messrs. Hobbs, Hart & Co., and the pattern registered, so that if new locks be at any time wanted, they can be supplied to suit the master key of their district. Drawings of the various patterns will be found in the I.G.F.'s Circular, No. 190, 16th October, 1871. This circular has been cancelled, but the drawings of locks shown in it still hold good.

Mantlet Doors.—Plate XXV.—It has been found by experiment, that if an explosion of P^2 powder occurs in a magazine passage, the wooden doors will be broken, but that "mantlet" doors will resist. Mantlet doors should, therefore, be hung in the magazines of coast-

batteries, in any positions which may seem suitable for limiting the effects of an explosion in a lift or serving-room, and more especially at the entrances to the cartridge chambers, so that there may be no risk of their being blown up.

The mantlet door consists of a strong framework of angle-iron, $1\frac{3}{4}$ inch by $1\frac{3}{4}$ inch by $\frac{1}{4}$ inch, galvanized, pivoted on sockets let into the roof and floor, and carrying two layers of paunch matting, 6 inches thick in all, such as is used about the guns.

The doors should be hung so that they cannot open more than half way, and are set on a slope, so that the action of their weight tends to close them.

They should always be carefully placed to open against the probable direction of the blast from an explosion, so that the effect of such shall be to shut them.

The doorways in which it is intended to hang mantlet doors, should, if possible, be 3 feet wide, and 6 feet 6 inches high, with a reveal 3 inches wide round the sides and top. (See I.G.F.'s Circular, 497, dated 9th November, 1886.)

In demanding the framework of a mantlet door it should be specified whether the sockets are to be fixed in stone or in concrete, and also whether the door is to be right or left-handed. The latter point is determined by assuming oneself to be standing at the hinge. Then if the door opens to the right it is right-handed, if to the left it is left-handed. It is as well to say that this simple rule does not apply to locks.

Mantlet doors can, if wished, be arranged for fastening with a padlock.

Shelving.—When the zinc cylinders in which the cartridges of heavy guns are kept, were first introduced, it was intended that they should be stored on skidding, lying on their sides like barrels; but it was soon found that the soft zinc got dented when resting only on the two points of support afforded by the horizontal bars of the skidding. The extraction of the cartridges was thus rendered difficult, and moisture was admitted to the interior by the injury done to the lid. It, therefore, became necessary to support the cylinders in a more continuous manner. This used to be done by an arrangement of shelving, used instead of the skidding.

These shelves were made of 2-inch boards, 10 inches wide and about 5 feet long, spaced 2 inches apart. They were supported on uprights and cross-pieces 4-inch by 4-inch, and were made removable, both that they might be taken out of the magazine and aired, and also for convenience in getting at the cylinders stored under them, which rested on the flooring. The shelves when in position were prevented from shifting by small pieces of hard wood, 4½ inches by 2½ inches by 1½ inches, screwed on to the cross-pieces, and which the corners of the shelves were cut to fit.

The uprights were framed at the feet into cross-pieces and longitudinals, 4 inches by 2 inches, and were further secured to the latter by brass T pieces, 2 inches wide by ¾-inch thick, and about 9 inches high and wide.

The spaces between these cross-pieces were filled in with batten flooring, which is also 2 inches thick, so that a level surface was formed on the floor.

The cartridge cylinders containing pebble powder used to be stored on their sides like powder barrels, as it was thought to have been determined by experiment that if stored on their ends the cartridges would set up and become difficult to extract, thus causing delay in loading. The difficulty, however, was eventually proved to have been due to defects in the cylinder and not in the cartridge, and consequently the cases are now stored on end.

Storage of Cylinders.—Cartridge cylinders are to be stored on end, and may be piled on one another three high. For convenience in moving the top tier a light stool, about 6 inches high, may be provided.

Care should be taken that the cylinders do not touch the walls during the process of stacking.

When the cartridge store is high enough to admit of more than three tiers, shelving may be provided to take the additional ones, but it will probably be found that this is seldom required.

Coast Battery Cartridge Store.—Coast battery cartridge stores can be made of any dimensions convenient for construction, so long as they have sufficient height and floor space.

The height at the springing of the arch need not be more than 7 feet 6 inches to allow of all cylinders being stored three high, and may be less for most guns if it be necessary to keep the walls low.

In calculating the floor space required for the different natures of cartridge cylinders, each pile may be taken as standing in a square of side equal to the diameter of the cylinder.

The following table shows the area of this square for the various guns, also the height of a pile of three cylinders, and the number of charges contained in it.

The amount of floor space required in a store may be obtained by multiplying the area of the square for the gun in question by the number of piles (not charges) to be accommodated.

CARTRIDGE CYLINDERS.

Nature of Gun.	Weight and Nature of Cartridge in one Cylinder.	Proportion of Charge.	Exterior Dimensions. Length in inches.	Exterior Dimensions. Diameter in inches.	No. of Charges in pile of 3 cylinders.	Height.	Area of the sq. in which 1 cylinder will stand, in feet and decimals.	Calibre of Gun.	Remarks.
R.M.L.	lbs.					ft. ins.		R.M.L.	
17·72in. or 16in.	112½ Pr.	¼-charge.	15·85	16·5	¾	3 11·55	1·8906	17·72	
12·5in., 38-ton.	105 P² or 80 P²	½-charge.	22·7	12·75	1½	5 8·1	1·1289	12·5	
12in., 35-ton.	110 P² or P	Whole charge.	29·6	12·25	3	7 4·8	1·0578	12·	
12in., 25-ton.	85 P² or P	do.	28·6	12·25	3	7 1·8	1·0578	12·	
11in., 25-ton.	85 P	do.	28·35	11·25	3	7 1·05	·8789	11·	The weights of the cylinders vary from 13½lbs. to 26¼lbs.
10in., 18-ton.	70 P	do.	27·1	10·25	3	6 9·3	·7296	10·	
9in., 12-ton.	50 P	do.	24·6	9·25	3	6 1·8	·5942	9·	
8in., 9-ton.	35 P	do.	23·05	8·25	3	5 9·15	·4726	8·	The handles project from ¾-in. to 1in.
7in., 7 & 6½-ton.	30 P or 2 of 17 P	1 full or 2 reduced charges.	31 0	7·25	3 or 6	7 7	·3650	7·	
BL.								BL.	
12in., 46-ton.	73¾ Pr., brown	¼-charge.	12·6	14·75	¾	3 1·8	1·5108	12·	
10in., 32-ton.	63 Pr., brown	do.	13·65	14·75	¾	3 4·95	1·5108	10·	10-inch ¼-charges may be stored 4 high.
9·2in., 22-ton.	85 Pr., brown	½-charge.	20·6	12·25	1½	5 1·8	1·0578	9·2	
8in., 12-ton.	45 Pr., black	do.	17·6	10·5	1½	4 4·8	·7656	8·	
6in., 5-ton, Mk. IV.	50 Pr.	Whole charge.	25·85	8·5	3	6 5·55	·5017	6·	
6in., 5-ton, Mk. V.	42 P²	do.	28·35	8·5	3	7 1·05	·5017	6·	

Tresidder's Cartridge Store.—A form of cartridge store proposed by Captain Tresidder, R.E., has been tried with success, and affords advantages which may render it desirable to employ it on low sites or where it is difficult to obtain sufficient overhead cover. As constructed for a 10-inch B.L. gun, it consists of a tunnel 49 feet 6 inches long, and about 4 feet 9 inches square in cross section. On rails laid along this tunnel runs a truck 23 feet long and large enough to carry 25 charges for the gun, which can be worked backward and forward by means of a winch and a wire rope. Across the centre of the tunnel, and rising 4 feet 6 inches high above its roof, is a small bombproof, 10 feet long and 4 feet 6 inches wide. From this bombproof access can be obtained to the truck, and cartridges can be taken from it and passed out to the numbers serving the gun. The truck is moved on as required so as to bring fresh cartridges into a convenient position for taking out. The advantage of this magazine lies in its small height, which gives facilities for its employment in certain cases. It is convenient for the service of the guns. Allowance should be made for a passage way along the tunnel for inspection.

2.—SHIFTING LOBBY.

Shifting Lobby.—Before entering a magazine or cartridge store, the regular magazine men put on a special suit of clothes; other men working in the store change their boots for magazine slippers; and inspecting officers put on slippers over their boots.

The place where this is done is called the "shifting lobby;" the term had at one time some reference to the manipulation of gunpowder, but it has now entirely lost that signification.

The general arrangement is in all cases the same, differing only in point of scale. There is a barrier, on one side of which the men put off their ordinary clothes, and on the other side of which they put on magazine clothing.

In the case of store magazines, the shifting lobby is often an isolated building through which all must pass who wish to enter the enclosure in which the magazines are situated.

For the main magazines at forts, and the large ammunition stores of coast batteries, plenty of shifting accommodation is required, and is usually obtained by partitioning off part of a passage. The amount of accommodation to be provided depends on the number of men to be employed in the magazine, which again depends on the nature of the ammunition, and the arrangements for issuing it.

In little expense cartridge stores in land works it is sometimes reduced to a barrier across the entrance doorway, and a couple of clothes pegs for the men's coats; but something of the kind must always be provided, and care must be taken in its arrangement, so that none but the men employed in the magazine chamber, and serving room if any, need pass beyond the barrier.

The magazine is considered to extend up to the barrier; outside it is common ground, where hob-nailed boots and lucifer matches are allowed.

The barrier itself is simply a hinged bar of wood, about three feet above the ground, which has to be raised to permit any one to pass. It may be noted that two barriers, with a space between them, used to be provided, but that now one only is considered sufficient, as laid down in I.G.F.'s Circular, No. 267, 1st October, 1877. The barrier may be 4½ inches by 3 inches in section. The uprights to carry it, if there be any, may be fixed by brass angle-plates to the batten floor, if there be one, or be let into the concrete.

In store magazines where gunpowder sometimes escapes from the barrels, a low panelling about one foot high, over which men can step, is carried right across the shifting room to prevent any loose grains getting into the unclean portion. Part of this should be a sliding panel which can be removed to admit of barrels being rolled in. On such occasions wadmiltilts are laid down on the floor.

It has been recently decided to apply this panelling at all barriers, with a view to prevent dirt and grit getting into the "clean" portion. It is evident that a slipper covered with grit is nearly as dangerous as a boot.

Pegs should be provided outside the barriers for the men's clothes, and inside the barriers for magazine clothes, in proportion to the number of men likely to use them, and a couple of seats are convenient. A foot grating should be provided before the outside seat.

Scrapers should be fixed outside the doors. These, by-the-bye, need not be of copper, as has been supposed by some.

For further details, with some lithographed examples, see I.G.F.'s Circular, No. 267, dated 1st October, 1877.

Ammunition Hatch.—In addition to the entrance for men it is sometimes convenient to have a special entrance for ammunition. This may be a hatch at the floor level large enough to admit of barrels being rolled in, and closed in such a manner that it can only be opened from the interior. It is advisable not to construct an ordinary doorway for this purpose. It is liable to be left open and used by men as the entrance to the magazine, without passing through the shifting lobby.

3.—LIGHTING.

Lighting.—Magazines used to be lighted either by daylight, or by hand lanterns carried into the magazine chamber, and these methods are still in use in store magazine establishments, where artificial light is not often wanted.

But in the magazines and ammunition stores of forts and batteries, which must be ready for use at all hours, and which are often buried beyond the possible access of daylight, better means are required, especially in coast battery ammunition stores, where heavy weights have to be moved and winches and other gear worked.

Hence the introduction of lamp passages, separate from the ammunition stores, from which the lamps can be inserted into openings, (which have retained the name of lamp recesses) situated in convenient positions for lighting the stores and passages. (*Plate* XXIII.).

There are two kinds of magazine lamp, the wall lamp and the overhead lamp.

Wall Lamps.—The wall lamp is $16\frac{3}{4}$ inches high, $9\frac{7}{12}$ inches wide, and $6\frac{3}{4}$ inches from front to back. It is made of copper, and burns a candle which is kept in position by being forced up by a spring like a carriage lamp. It will burn for eight hours. Enough chimneys are issued for use in draughty places.

This lamp is intended to stand in a recess or on a shelf.

A variation on this, called the *Both-ways Lamp,* is glazed on both sides, and is intended for lighting passages.

Lamp Recesses.—The forms of lamp recess are many, most of them being only rendered necessary by want of arrangement in laying out the lamp passages, or by the exigencies of alterations to old works.

The simplest form, and the only one generally necessary to use, is a rectangular hole cut through the wall, and closed at the end by a pane of glass set in a brass frame. This frame is 1 inch wide all round, and $\frac{1}{4}$ inch thick. From it projects a rib $\frac{1}{2}$ inch thick and ½ inch deep. To this rib is secured a flat frame of brass, 1 inch wide and $\frac{1}{8}$ inch thick, the inner superficial dimensions of these two frames being the same, and in the space between them is fitted the india-rubber in which the glass is set. The indiarubber may be a tube, slit down. This separation of the glass from the brass by strips of indiarubber has been found necessary to prevent it being broken from the concussion of firing. This frame should be double; the outer one fixed; the inner one hinged to it to open into the magazine, so that the glass can be got at for cleaning. It is almost impossible to clean the glass properly at the end of a long recess.

The outer frame is Z shaped, 1 inch wide and 1 inch deep. It fits round the edge of the recess, and is attached to the wall by lugs and screws. To it is hinged the inner frame.

The frame is closed by a simple lock and "railway door" key.

A stop should be inserted in the floor of the recess to prevent the lamp being shoved too far forward, and a brass bar fixed across to prevent its being tilted against the glass, and an escape for the smoke may be provided above.

If the lamp recess be low down, and in such a situation that it might be struck by a man's shoulder, or the end of a cartridge cylinder, it should be protected externally by a grating of $\frac{1}{8}$ inch brass wire.

The glass, by-the-bye, should be plain strong sheet or plate glass. I have been in a magazine in which bulls-eyes of considerable curvature were used in the lamp recesses. The result was that there was a bright spot of light on the opposite wall, and the rest of the magazine was in darkness.

The smallest size used for the glass frame of a lamp recess is 1 foot 3 inches by 1 foot 3 inches; this is shorter than the lamp. The most convenient size is made to suit a recess 1 foot 9 inches high by 1 foot 3 inches wide. There are other sizes to be got, particulars of which may be found in the W.O. contracts.

It may be necessary to put two lamps back to back to light a passage in two directions. In such a case a projecting box can be procured, in plan 3 sides of an octagon, which must be set on a slate or hard stone slab. It requires an opening 2 feet wide to be cut in the wall behind it. It is usually better to have two ordinary recesses near one another.

Sometimes it is necessary to put a lamp at the end of a long recess, so that it would be beyond the reach of a man's arm. Then a little tray to carry the lamp must be used, running on small zinc rails, and pushed in or pulled out by a stick with a hook at the end.

If it is inconvenient to use the stick, the tray can be hooked to an endless chain running over two pulleys, one at each end of the tube or recess.

Occasionally a lamp has to be passed across a magazine passage to light a chamber on the other side; in that case a tube of slate or sheet iron has to be used, down which it can be pushed on the tray just mentioned.

If it be wished to light the passage from this tube, which affords a convenient position for doing so, a glazed frame can be inserted in the side, and the lamp put on a special tray which carries it sideways.

It may sometimes be necessary to lower down a lamp to its recess from some height too great for a man to reach with his arm. In that case it can be let down by a brass chain and pulley, and guided into its place in the following manner:—

Two pins are inserted in the sides of the base of the lamp, and these pins fit in grooves cut in two boards set up, one on each side of the shaft down which the lamp is lowered, so that the lamp is guided in its descent. These grooves are curved at the lower ends, so that the lamp is moved forward close up to the glass.

Overhead Lamp.—The overhead lamp is cylindrical in form—somewhat like a railway carriage lamp, but it burns a candle like the wall lamp. The lower part, which is of glass, is 8 inches deep and $8\frac{1}{2}$ inches in diameter. The upper part, of copper, is $8\frac{1}{2}$ inches high and 9 inches diameter. The difference in the diameter of the two parts forms a shoulder on which the lamp can be supported.

The overhead lamp is always used by being lowered down a tube. The lower end of this tube would be made of iron, and the lower edge would be either turned in, or have a ring of angle-iron rivetted on to it to form a rim on which the lamp may rest. The rim would be covered with indiarubber. It will be seen that when the lamp is not in position, there is an open communication between the lamp passage and the magazine, which is objectionable.

A wire guard should be fixed round this lamp in low passages.

The various methods of using magazine lamps have been shortly described, as cases may occur in which the simple recess cannot be used, but all other forms should be avoided as much as possible.

Lamp Recess Doors.—When lamp recesses are in places which are accessible to others besides the lamp man, the backs must be provided with iron doors $\frac{1}{4}$ inch thick, and locked with a key like a railway door key. This is to prevent unauthorised people meddling with the lamps, and it is also intended to diminish the chance of any accident which might knock the lamps forward into the magazine.

Arrangements must be made, by air-bricks or other means, to admit air to the lamps.

When the recess is made in an outside wall, of course it becomes a small window in daytime, which is useful in places such as laboratories where work is usually carried on during the day.

Number and Position of Lamps.—The service lamps give a very good light, and not many are needed for a magazine.

Two are sufficient for an ordinary small expense store; eight as a rule are enough for each chamber of a large store magazine, two for the centre passage, and one for each side one, at each end.

Ammunition passages can be lighted from the ends if there are no bends in them. Shifting rooms should be provided with lights.

There should always be a good light near the entrances and exits of the lifts, where hooks have to be adjusted and the winches worked, and in placing the lamps care should be taken that the men do not necessarily stand in their own light when at work.

Height above Floor.—A good height above the floor for a wall lamp is 5 feet to the under side of the recess; in a large magazine a little more, but not much, or there will be a dark space underneath.

Lamp Passages.—Lamp passages may be made 2 feet 6 inches wide, and run round or intersect the magazine buildings at the general floor level, but sometimes it is convenient to divide a passage horizontally by inserting a floor of stone, concrete, or slate slabs, and using the upper portion as a lamp passage. This upper portion need not be more than 5 feet high.

It is best to make the entrance to the lamp passage entirely distinct from that to the magazine, but it can be entered if necessary from outside the barrier in the shifting room; never from inside the barrier.

Magazine lamps may be carried into shell stores, and the latter may therefore be utilized as lamp passages if otherwise suitable. It must be remembered that the shell stores themselves must be lighted in some way, and a lamp passage is often a convenient way of doing this. If lamps are carried into a shell store, a passage-way has to be left clear for them.

Lamp Room.—If there are many lamps, a lamp room is required where they can be kept and cleaned. It must be lighted by daylight, and must contain some shelves for the lamps, and a bench or shelf at which they can be cleaned. If the entrance to the lamp passage is a little widened, it will often do very well. In other cases the lamps are kept in the Artillery store.

For regulations concerning lamps in magazines, see the Equipment Regulations.

Effect of an Explosion on the Lamps.—An experiment was made in 1880 to determine how lamps were affected by the explosion of gunpowder in their vicinity. It was found that an overhead lamp inserted into a shaft from the gun floor was invariably put out by an explosion on that floor: therefore no lamp recesses should be in direct communication with the gun floor. The wall lamps below were unaffected by the explosions above until 160 lbs. P² were fired in the top of the lift, an experimental trap-door which was in the lift being left open. The explosion broke the glass of the recess of a wall lamp immediately opposite the bottom of the lift, and knocked down the lamp without injuring it; the other lamps in the lamp passage were quite unaffected.

The explosion of 80 lbs. P² in the magazine passage put out the other wall lamps in the lamp passage without breaking the glasses separating them from the magazine chambers, and it broke the overhead lamp in the magazine passage. It therefore appears advisable not to put a lamp recess exactly opposite the opening of a lift, but a little to one side; otherwise, the recesses are no source of danger.

4.—SHELL STORES.

Shell Stores.—Shell stores are required on all works, as shells are kept filled and all filled shell should be under cover, not necessarily bombproof. The operation of filling shell is one requiring care, skill, and time, and is therefore best done by well-instructed men at a central establishment.

All projectiles above and including the 6-inch B.L. are stored on end; below that size they are piled lying on their sides, and the 6-inch may be stored on their sides if the stores are not large enough otherwise.

In calculating the floor space required for the different natures of heavy shells, each shell may be taken as standing in a square of a side equal to the diameter of the shell; this allows sufficient room for manipulation.

The following Table shows the area of this square for the various calibres. The amount of floor space required for the shells in a

store may be obtained by multiplying the figure opposite the calibre by the number of projectiles to be accommodated.

Calibre of Gun in Inches.	Area of Square in which one Shell will stand in Decimals of a Foot.	Calibre of Gun in Inches.	Area of Square in which one Shell will stand in Decimals of a Foot.
17·72	2·1805	10	·6944
16·0	1·7777	9·2	·5890
13·5	1·6240	9	·5625
12·5	1·0851	8	·4200
12	1·0000	7	·3402
11	·8400	6	·2500
10·4	·7511		

Shell have to be grouped in a store by calibres and by natures. It will not do, therefore, to make stores too exactly to the size required to hold the number to be accommodated, but space must be left for arranging, moving, and manipulating them.

The requirements to be met by a shell store are few in number: they are, shelter from the rain, which might penetrate by the fuze holes into the shells; security against the plugs of the shells being unscrewed, and the powder extracted or maliciously fired; and protection against the direct blows of an enemy's projectiles. It is evident that these can be met by a light building placed behind the rampart or at the end of a traverse, but it is usual to appropriate a casemate for this purpose. The bombproof cover will be useful in war time, when most of the shells will be up by the guns, and the remainder can have some slight shelter improvised. It is, moreover, inexpedient to construct light buildings in a work: they take up space, and are liable to injury from splinters. Conveniences of construction and storage often lead to the shell stores being combined with the cartridge stores. This used to be the universal arrangement, and in works of small area, where the ammunition stores are below the level of the gun emplacements, it will probably continue to be adopted.

There is, however, a strong feeling that the proper place for all projectiles in war time is close to the gun, where they would be ready for use; and if they are to be there in war time, why not in peace?

With Palliser and case shot there is no difficulty. That only arises with common and shrapnel shell which have fuze holes in their heads. These, could, however, be secured, if placed in a row, under a hinged bar, hollowed out at intervals in such a manner as to take the heads of the projectiles. This bar might be either of wood, or be an angle-iron, with filling-in pieces across the hollow of the angle-iron at intervals; or be of metal cast to the shape. It should be padlocked down at the end, when it would be difficult if not impossible to remove the shells. For complete security their bases might be placed in sockets.

For shells with base fuzes, which will, probably, be in time introduced into the service, an arrangement might be adopted which has been successfully used with some 11-inch Palliser projectiles at the time when they were used as shell, and were filled with powder through the base. It consists of a sort of grating of light ironwork like a ladder slipped over them, and supported on brackets let into the wall at about two-thirds of their height. When in position it is secured at the ends and padlocked down; it prevents the projectile being overturned.

These arrangements would be too costly for the smaller shells—6-inch and under—a supply of which might be kept near the gun in recesses such as will be described further on.

As they occupy but little room, they are, however, comparatively easy to find accommodation for; and as they are light and easily transported, there is not so much objection to keeping them in some central store, and bringing them to the gun when it is likely that they will be wanted.

Fittings of a Shell Store.—No shelving, wall battens, or batten flooring are required for a shell store (see I.G.F.'s Circular, 451, dated 1st October, 1885), except when studded projectiles are stored, when batten flooring should be used to avoid all chance of injury to the studs. This includes all 64-pounder and 7-inch R.M.L. ammunition. It should also be used to protect asphalte floors covered with cork composition from injury. The batten flooring should be of the strong pattern as described for magazines.

It is as well to mention that at one time it was considered advisable to use batten flooring in all shell stores. It was thought the shells would break up any stone or concrete surface, and they

would thus get gritty and difficult to load with. This, no doubt, applies more particularly to R.M.L. guns, but it is possible that it may again be considered desirable to adopt batten flooring generally in shell stores. In any case it would not be advisable to remove batten flooring already laid merely for the sake of leaving the concrete bare. R.M.L. shells, with projecting plugs for gas checks, have to be kept upright by small packing pieces of wood. These are supplied by the Artillery.

No Shifting Lobby for Shell Stores.—From this description of the manner of storing shells it will be gathered that no shifting arrangements are required for shell stores.

An exception to this has, however, to be made when a passage is common to both a cartridge and a shell store, as is the case in some of our existing casemated works. Precautions must then be taken as for the former. There is, however, a manifest absurdity in admitting iron projectiles into a cartridge passage provided with copper fittings, and the arrangement should be avoided whenever possible. Often the barrier can be placed between the portion used for shell and for cartridges respectively.

Shell Trucks.—Heavy shell are moved about on trucks resembling those used by railway porters.

That used in the shell stores has two wheels and two legs. The shell is taken on to the truck in a vertical position, and moved about in a sloping one. The truck is 4 feet 1 inch long and 1 foot $7\frac{1}{2}$ inches wide over the wheels.

The truck used on the gun floor has four wheels, so as to be easily moved over projecting racers. It is 4 feet 8 inches long, and 2 feet wide over the wheels.

It has, in some cases, been found convenient to move projectiles by means of an overhead traveller. The following is a description of a form which has been employed with satisfactory results:—

Two steel angle irons planed to 4 inches by $1\frac{5}{32}$ inches by $\frac{5}{8}$ inch are suspended opposite one another, so that their edges are $4\frac{3}{16}$ inches apart. Between them runs a small four-wheeled truck, to which is suspended a Weston pulley for raising the projectiles, which can be slung in a selvagee. To economize head room the upper block of the Weston pulley can be made in one with the traveller.

The angle irons are hung from curved iron suspenders attached to 1-inch bolts built into the arch.

The necessary dimensions are:—

From upper surface of lower flange of angle iron,
to clear top of truck, at least... ... ... 5½ inches.
From upper surface of flange to floor, at least... 3 feet.
Distance apart of suspenders, up to ... ... 6 feet.

Fuze and Tube Shelf.—All shell stores and shell recesses should be provided with fuze and tube shelves, lettered for tubes and for percussion and time fuzes as laid down in I.G.F.'s Circulars, No. 204, dated 24th June, 1873, and No. 416, dated 1st December, 1884.

These should be fixed in some convenient position near the door.

The tubes and fuzes are packed in tin cylinders. The following table shows the number of fuzes of the kinds at present in use that are packed in a cylinder, together with the dimensions of the latter, and gives the same information for the two sizes of tubes of which the larger is used for 10-inch R.M.L. guns and upwards, and the other for smaller natures.

Name of Tube or Fuze.	Size of Box in Inches. Length.	Size of Box in Inches. Diameter.	Number the Box will contain.	Remarks.
Tubes, friction, copper, long ...	5·3	2·8	25	
,, ,, ,, short ...	3·4	2·8	25	
Percussion, Direct Action	2⅛	4·1	5	Can be used for all common shell, M.L. and B.L.
Middle Percussion, Experimental	2½	4·1	5	Proposed for common shell for B.L. guns.
Time and Percussion (T. and P.)...	3½	2½	1	Can be used with all B.L. shell, but not intended for "percussion" only.
Time, 15 secs., M.L.	3¼	4·	5	For M.L. shrapnel.

The existing pattern of fuze and tube shelf consists of four pigeon-holes, each about one cube foot in size, for different natures of fuzes; the shelf formed by their tops is used for placing the tubes on. This gives accommodation for fuzes for about two B.L. or three R.M.L. guns.

Several new patterns of fuzes are likely to be introduced, and they may require some modifications in the method of storing them. The Artillery must be consulted as to their requirements in this respect, when the new fuzes come into use, but the accommodation required, as shown by the table, is not likely to be materially altered.

Wedge Wads.—A shelf for wedge wads is useful, and should be provided when R.M.L. guns are mounted.

Fuze and Tube Store.—It will be found convenient in cases where there are a large number of guns in a battery to devote a small chamber to the storage of tubes and fuzes.

MAGAZINE ACCESSORIES.

Having described the magazines themselves, there remain to be noticed the lifts for hoisting ammunition, recesses, and other accessory buildings and fittings.

5.—LIFTS.

Lifts for Heavy Guns.—*Plates* XXVI., XXVII., XXVIII.—In those cases in which the ammunition stores of coast batteries are in a basement, arrangements have to be made for raising the cartridges and projectiles to the gun floor; this is done by means of Lifts.

Lifts are shafts cut in the walls, piers, or arches of stores and casemates, and provided with gear or tackle for raising the ammunition.

There are two types of lift now in use, which may be distinguished as the "circular" lift and the "tray" lift. The new form, or "tray" lift, has been introduced to get greater security, and also increased rapidity of delivery. This is necessary in supplying the large cartridges, made up in several pieces, which are used in the long B.L. guns. By this lift cartridges and projectiles can be delivered indifferently. It should be used for all B.L. guns of 9·2 inches calibre and upwards, and also for 12·5-inch R.M.L. guns in new emplacements. For the smaller heavy guns the old pattern of lift, which is much less costly, can still be employed, unless for any special reason rapidity is desirable. This would be the case if it were possible that shell and cartridges might have to be served during action from stores in a basement. It would then be better to have one new lift than two old ones.

The old pattern of lift is circular in plan, and usually 18 inches in diameter, though the lifts for the larger heavy guns are best made 1 foot 9 inches in diameter.

Cartridge lifts for 12·5-inch 38-ton guns are provided with crabs for raising the ammunition: those for lighter guns do not require them.

The circular cartridge lifts, if used for any of the new B.L. guns larger than the 8-inch of 13 tons, will require crabs.

All shell lifts for heavy guns are provided with crabs.

Cartridge cases are placed in a brass cage to be lifted. Shells are raised by means of a clip with projections that fit into the extractor holes in the head of the shell. Extractor holes will not be formed in the heads of B.L. shells, and cages will therefore have to be provided for them, whenever they are to be hoisted by circular lifts.

Lifts may be made in the walls or arches of ammunition stores, and may issue in the floors or walls of casemates, or of bombproofs, or in the revetments of the parapets of barbette batteries.

The best place for them to open is in the walls, not in the floors.

They should be kept back at least 6 inches from the face of the wall, in order to give room for a door.

In the ammunition store the opening of the lift may be of any convenient height, say 6 feet 6 inches, and should be carried down to the floor level.

In the battery the top of the lift must be at least 6 feet above the floor, and may with advantage be a foot or more higher. This height is necessary in the case of cartridge lifts, to bring the bottom of the cage in which the cartridges are hoisted above the floor, and in shell lifts to enable the shell to be swung out of the lift. It is not necessary to make the actual door of the lift so high as this, as the cartridge cage is only 4 feet high, but it is necessary to get the overhead block as far up as possible, as there is the hook, the counterpoise, and the overhead block to allow for, measuring about 1 foot 9 inches in all.

Plates XXV., XXVII.—The drawings show a shell lift for an open battery, with various details connected with the mode of fixing the crab, and the overhead block, and with the trap door which is provided for the shell to rest on, so that it may be more easily got out from the lift opening.

The differences between a shell and a cartridge lift in the arrangement of hoisting gear, are also shown.

The lifts for a casemate battery are exactly the same as those for a barbette battery.

If it be convenient to make it so, the exit of the lift may face in a different direction from the entrance. The only point to guard against is that the chain from the crab does not come in front of the door.

Special arrangements can be applied to the crab handle in places

where the space may be too confined to work it at the lift; it may be lengthened out, or gearing may be used so that it may be worked at an angle.

If it be wished, the crab may be worked at the top of the lift instead of the bottom, but the latter position is usually more secure, and keeps the gun floor more free of men.

Steel wire rope is used both in shell and cartridge lifts. For the former it is $1\frac{1}{4}$ inches in circumference; for the latter $\frac{3}{16}$ inch in diameter, covered with line for ease in handling.

Speaking tubes should be fitted to all lifts, from the top to the bottom, for communicating instructions.

The overhead block is a universal pattern to take all weights up to 800 lbs. It consists of a pulley working between two 3-inch by 3-inch by $\frac{1}{2}$-inch angle irons, which span the top of a 1 foot 9 inch lift, and rest on its sides. It is thus independent of any covering stone.

The distance between the underside of the covering stone and the bottom of the angle iron should not be less than 7 inches. The pulley is $9\frac{1}{2}$ inches in diameter. It is shaped to take a wire rope of about $\frac{1}{4}$ inch in diameter.

Widening Top of Shell Lift.—In the case of lifts for very heavy projectiles, such as those of the 38-ton gun, it is desirable to widen the top of the lift, so that the shell-truck may be pushed in and the projectile lowered upon it. A width of 2 feet 3 inches is required to admit the shell-truck, and the widening should extend up to six inches from the axis of the lift.

If this widening be impracticable an issue-bar can be used, which has been successfully applied to the shell lifts of 38-ton R.M.L. guns.

Issue Bar.—It consists of a bar of iron, 3 inches by $\frac{3}{4}$ inch in section, hinged at its lower end at a point in the back of the lift 3 inches above the floor level, and at the upper end formed into a sort of fork. It is kept upright at the back of the lift by a spring catch.

Its action is as follows:—When the projectile has been raised to the top of the lift, the bar is pulled forward, and the projectile lowered, till the shell clip catches on the fork at the top of the bar; on the shell being further lowered, the bar pivots forward and forces the shell out of the lift, so that it can be easily got at. If this issue bar be used, the overhead block must be fixed on a swivel.

Lifts for Medium Guns.—Lifts which are intended to supply ammunition to medium guns, such as are used in land works, should be of sufficient diameter to allow of metal-lined cases being passed up them; the latter are 16¾ inches by 16¾ inches by 20⅝ inches. The lift should be 2 feet 3 inches in diameter, and should be provided with a ring bolt in a central position above, and an eye-bolt for a leading block below, in any convenient position. The tackle will be supplied by the Artillery. The same fittings are required for both shell and cartridge lifts.

Lift to take Barrels.—The same kind of lift, which is commonly made square and not circular, should be used in any case in which it may be required to accommodate barrels. It is then called a "general" lift.

Shell Lift for 6-inch B.L.—In order to gain increased protection to the tops of shell lifts for 6-inch B.L. guns, the projectiles may be raised horizontally, being suspended from the tackle by means of a selvagee. A lift for this purpose must be 2 feet 3 inches in diameter if circular, or 3 feet by 10 inches if rectangular, and the top must be not less than 3 feet 3 inches above the sill of the delivery opening. The ordinary tackle will be used, set so that the shell will be hung in the centre of the lift. It will be convenient to have a flap, about 1 foot wide, at the top of the lift, to lower the shell on to. This form of shell lift can be used for medium guns generally.

Davit (Plate XXIX.).—It is occasionally convenient to hoist ammunition up by the rear of the rampart. In that case a davit can be used, made of round iron, pivoted, and having an overhang of 3 feet, and with an eye at the end to take the hook of a block. It can be 2 inches in diameter to lift 1¼ cwt, but must be increased to 3¼ inches to lift 8 cwt. The latter will lift all projectiles up to those for the 12·5 M.L. guns.

Tray Lift (Plate XXVIII.).—This lift, as its name implies, consists of a series of trays, which are attached at their extremities to endless chains passing over pulleys, above and below.

The trays pass up one side and down the other of a central partition. Their motion is interrupted only to receive and deliver ammunition, and several trays can be carrying loads at the same time.

The trays are suspended in such a way as to run no danger of overturning, even when passing the pulleys, whether loaded or empty.

The distances between them are so proportioned that when one tray is at the ammunition floor level ready to receive a load, another is at the gun floor level ready to deliver one. The unavoidable delay is thus minimized.

The trays will accommodate either cartridges in zinc cylinders, or projectiles lying on their sides. By the adoption of this position the height of the opening of the lift on the gun floor can be reduced to about 2 feet. Its width has to be sufficient for the largest projectile or cylinder; or 3 feet 4 inches for guns up to 10 inches calibre.

The lift is actuated by a winch-handle and gear acting on the lower set of pulleys.

The whole of the machinery is enclosed in a cast-iron casing, which has to be built into the work, or at least lowered down into a place prepared for it before the upper portion of the parapet is completed.

The trays are so made as to close the space between the central iron plate partition and the sides, as they travel up and down. This forms a valuable safeguard against the accident of an explosion passing down the lift.

The gear for working the lift can be made either right or left-handed, as may be most convenient.

A lift can be made to deliver on the same side to that which it receives, or the opposite. The former arrangement is preferable, and should be adopted whenever possible, because the trays are then made to deliver at one side only, and can carry their load in a somewhat safer manner than when this is not the case.

The heights from floor to floor, for which these lifts are used, should vary only by intervals of six inches, to suit the pattern of the chain, which has links three inches long. Thus the heights should be 15 feet, 15 feet 6 inches, 16 feet, and so on. With some dimensions, the lifts which receive and deliver at opposite sides can be made to vary by 3-inch intervals.

In order to fulfil the condition that a tray should be simultaneously at the gun floor and magazine floor level, certain proportions have to be observed. It results from these that the distance between the upper and lower pulleys does not vary as the distance between the floors.

The axis of the upper pulley is always kept at the same height above the gun floor, about 1 foot 4 inches, and consequently the relative levels of the lower pulley and the floor vary, and a pit of greater or lesser depth has to be formed to allow the trays to pass at the lowest point, and to accommodate the man at the winch-handle. The depth from the floor to the bottom of the pit under the trays varies from 2 to 3 feet; that to the floor under the winch-handle is 1 foot 4⅜ inches less.

The total length of the recess for the lift from the front is 2 feet 8 inches, and that for the winch men is 1 foot 2 inches deeper.

The total width of the outside of the iron casing for the lift is 4 feet $5\frac{1}{4}$ inches, exclusive of certain flanges which project in places about 3 inches more. The recess for the men at the winch is 2 feet 9 inches wide, beyond the casing.

The iron work for these lifts is made under the direction of the Inspector of Iron Structures, and delivered ready to be bolted together and set up complete in its place.

The details given above are sufficient to enable the work in the neighbourhood of one of these lifts to be arranged in a convenient form, but none of the masonry about it should be completed permanently until a drawing has been received showing the exact form of the lift as it is to be delivered.

Demanding a Tray Lift.—In demanding a tray lift it is sufficient to specify the height from floor to floor, and whether it is to receive and deliver on the same or opposite sides.

Return Lifts.—Every fort or battery provided with basement shell stores should have a lift for the return of projectiles used at drill, and for equipping the magazines, if no other suitable entrance exists.

The ordinary circular shell lifts are not to be used for lowering projectiles, wherever the shell crabs have to be worked in a dark and confined space, nor are the new tray lifts adapted for this purpose.

There is no special fitting for a return lift, but it might be conveniently provided with a Weston's pulley, which is very well suited for lowering heavy weights. This could be used for this purpose in an ordinary circular lift.

Special Forms of Lifts.—Table Lifts.—There are several "table" lifts in use with heavy R.M.L. guns, intended to raise both cartridges and projectiles. They consist essentially of a small table provided with trucks, which work on one or more vertical guide-bars. The table is hauled up and down by means of a winch working a chain or wire rope passing over a pulley. They are slow to work, and their place would be efficiently taken by the "tray" lift.

Ladder Lifts.—Various peculiarities of construction have caused the use of a special form of cartridge lift in the Spithead forts. It may be described as an endless chain ladder, to the rungs of which the cartridge cases are hung.

It differs from the "tray" lift in having an automatic delivery, and it can be thus always kept in motion. It is well suited to its place, but for general use the "tray" lift seems preferable.

A special form of shell lift will also be used at Spithead, with an automatic delivery.

100-Ton Gun Lifts.—The ammunition for the 100-ton guns is raised by means of an hydraulic hoist, similar to a "lift" in an hotel.

The complete charge, cartridge and projectile, is placed on a special truck, run on to the top of the hoist, and turned into the proper direction. It is then raised to the muzzle of the gun, and rammed home off the truck.

The 80-ton R.M.L. guns in Dover turret have another very special form of lift, which it would serve no useful purpose to describe here.

Hydraulic Lifts.—Some lifts will be introduced worked by hydraulic presses and multiplying gear, in the same way as hydraulic cranes.

Security of Cartridge Stores.—Various experiments were carried out in February, 1880, to determine what was necessary to be done to secure the cartridge stores of heavy guns from the effect of an explosion passing down the lift. Some old casemates at Eastbourne were altered to resemble magazines, with lifts, lamp recesses, and doors for this purpose. The results may be summed up as follows:—

160lbs. P^2, the charge for a 38-ton gun, hung up in the top of a lift and fired would explode a cartridge in its zinc cylinder standing in the bottom of the lift; but it would not explode it, only heat it and knock it down, if standing 18 inches in front of the lift below.

Trial of a Trap-door.—The lift was then provided with an iron trap-door in two halves, with the necessary openings for the ropes to go through for hoisting the cartridges, and this was fixed one foot below the gun floor. With this protection, 160lbs. P^2 fired in the top of the lift did not explode a charge in the bottom of the lift. The trap-door was a little bent, but it might have been made a little stronger without any inconvenience.

This showed that the provision of one trap-door in a circular lift is sufficient to prevent an explosion passing down it, for although the trap door would be open when the charge is going up, yet at that precise time no charge could be in the top of the lift. An explosion taking place not in, but only near, the lift will not pass down it with sufficient violence to do harm.

In consequence of this experiment, a safety trap was recommended for use in circular lifts, but has not been much used. The danger to be guarded against is remote, and might be entirely done away with by a little care in keeping cartridges away from the openings of the lift. The fitting is expensive; it may get out of order and block the lift, and may delay the service. The description is, however, given on the chance of its proving useful in some case of a specially exposed ammunition service.

Safety Trap for Cartridge Circular Lifts.—This is entirely constructed of gun metal, and for an 18-inch lift consists of two metal flaps, each $21\frac{1}{2}$ inches long by $9\frac{7}{8}$ inches wide and 1 inch thick, hinged in a frame of L section. The inner edges of the flaps are cut away to a depth of half-an-inch over a space of 4 inches in the centre, to give room for the wire rope which carries the cartridge cage, and at one side they are also cut away to let the other end of this rope pass to the crab. Here two little guide pulleys are fixed under the frame.

On the other side is the gear for opening the trap. This consists of two bars jointed to projections under the inner edges of the flaps, and to a cross bar fixed to the head of a vertical rod. The first two bars are 5 inches long from axis to axis of their pivots; the cross bar is 8 inches long. Raising the vertical rod raises the jointed bars which push back the flaps. The vertical rod, which works in guides, is actuated by a lever 2 feet 9 inches long, fixed on the side of the lift, about 5 feet 6 inches above the floor, so as to be easily reached. The weight of the flaps is partly counterpoised by a weight on the lever, so that when open the trap will keep open, and when closed will keep closed. The position of the lever is always on the opposite side of the lift to the crab.

In order to accommodate the flaps in their frame, a portion of the lift for about 12 inches in depth must be made rectangular. The sides of the rectangle are 11 inches from the axis of the lift, except the side where the opening gear comes, which is $12\frac{1}{4}$ inches from the axis. Sinkings are also required to take the various parts of the opening gear, which should not encroach on the lift. The position of the safety trap in the lift should be so arranged that while there should be masonry enough below it to bear it up against an explosion—say 6 inches over the opening of the lift—yet it should, if possible, be far enough below the level of the gun floor to permit of the flaps being closed before the cartridge begins to emerge from the lift, *i.e.*, at least 4 feet down for a 10-inch R.M.L. gun.

The frame and other portions of the trap are connected with screws in such a manner that they can be put together when in position in the lift.

The trap for a 21-inch lift is similar to the above but with the dimensions proportionally increased, the thickness remaining the same.

Drawings of these traps numbered 50,786 and 50,787, were issued on 12th July, 1884.

Security of Tray Lifts.—With these lifts the cylinders are necessarily being put in and taken out at the bottom and top simultaneously, and there may be one or more on the way up also. This would constitute a serious danger, but that the trays of the lift are strongly made, and shaped so as to fit close to the sides, which makes them safe.

6.—RECESSES.

Ammunition Recesses.—Plate XXX.—Recesses are used for the storage of small quantities of ammunition close to the guns, where there is any probability of there being delay or danger in getting it from the expense stores when in action, either from their being at some distance off, or from several guns having to be supplied from the same point.

Recesses may be made of various forms to suit the situations they occupy, but the dimensions given below will be found generally convenient.

Recesses for Medium Guns.—The recess for medium gun ammunition, whether for shell or cartridges, may be made 3 feet wide, 2 feet 6 inches deep, and 3 feet 9 inches high.

This will contain twenty-three 64-pounder R.M.L. or 7-inch R.M.L. or 6-inch B.L. shell, together with a fuze and tube shelf, 10 inches deep, under the top of the recess, or it will contain four metal-lined cases containing cartridges, or twelve charges for the 6-inch B.L. gun in zinc cylinders.

If made 4 feet deep it will accommodate twice as much R.M.L. ammunition.

The floor may be raised 6 inches above the ground to keep it dry, but it must in most cases be kept as low as possible for the sake of protection.

The floor may be made either of stone or concrete.

When the recess is actually used for the reception of ammunition, pieces of wood may be laid down to take it, but these should not be permanently fixed as they are likely to perish from damp.

The door should be strongly made of 2-inch stuff, in two leaves, and hung on a $4\frac{1}{2}$-inch by 4-inch frame.

As recesses are usually near the guns, and consequently the blast from the firing has a considerable tendency to blow open the doors, the frame will have to be held back by iron straps let into the wall, and the hinges and fastenings must be very solid. The former should be strap hinges of 2 inches by ½-inch iron; the latter should consist of bolts at top and bottom and in the middle a swing bar of 2½-inch by ½-inch iron, secured by a padlock. Hooks should be provided to hold the doors open in a wind.

It has been found that instead of attempting to resist the effect of blast by wrought iron, a bar of ash can be used to keep the doors of a recess closed during firing. The elasticity of the ash allows the doors to yield sufficiently to preserve them from injury. This might be provided, together with a hook on either side of the door to carry it, in cases in which the blast is productive of any inconvenience. The ash bar may be 3 inches by 1½ inch in section.

Recesses for Heavy Guns.—The recesses for heavy guns are similar in general construction to those for medium guns, differing only in size.

They may be made 3 feet 9 inches wide, 3 feet 9 inches deep, and 5 feet high. This will take thirty-two 10-inch R.M.L. cartridges, or sixteen 10-inch shells, or nine complete charges for the 10-inch B.L. gun.

The floors of the shell recesses must be close to the ground, say 2 inches above it, and a little moveable wooden ramp should be provided for convenience in getting out the projectiles.

Recesses for Q.F. Guns.—These may be 3 feet 6 inches long, 3 feet deep, and 2 feet 3 inches high. This will accommodate six boxes of 3-pounder ammunition containing in all 96 rounds, or eight boxes of 6-pounder ammunition containing in all 88 rounds.

If they can be made 4 feet 3 inches high without loss of security, they will hold two rows of boxes, and thus twice the number of rounds.

They need not be provided with doors unless it be intended to store ammunition in them permanently. In that case they should be made 2 inches deeper.

The ammunition for the 14-pounder Q.F. gun (not in the service) is made up in a similar form to that of the smaller guns. Each charge is at present 4½ inches in diameter over the base flange, but less over the body, and 17⅛ inches long.

The best form of recess would be one with a series of shelves carrying rows of charges side by side with their bases outwards. If such a recess were made 3 feet 9 inches long, 2 feet deep, and 3 feet 9 inches high, it could be fitted with 5 shelves, each 2 inches

thick, and carrying 10 charges, 60 rounds in all, including those on the floor.

The ammunition for the 4·7-inch Q.F. gun is made up with the shell separate from the cartridge. The latter is enclosed in a brass case 6 inches in exterior diameter, and about 15 inches long, but the pattern is not yet definitely settled.

The shells will be treated like other projectiles of a similar weight. The cartridges will perhaps be stored in boxes, which would be placed in recesses without any fittings, or will be placed on shelves.

It may be here remarked that recesses will form very necessary parts of emplacements for Q.F. guns, since they will facilitate the supply of ammunition, a matter of primary importance with these weapons.

It will often be found convenient to make a long shallow recess at the foot of a wall, or round the parapet of a gun emplacement, to take a single row of projectiles, so that they may be handy for use and at the same time not in the way. This form of recess is, in fact, generally used in modern works. The dimensions of course depend on the size of the projectiles to be accommodated.

A height of 3 feet 3 inches will be sufficient for the 10-inch B.L. projectiles, 3 feet for the 9·2-inch, and 2 feet for the 6-inch B.L. The depth may be equal to the diameter of the shell.

7.—SHELL AND CARTRIDGE-FILLING ROOMS.

The provision of shell and cartridge-filling rooms is governed by the following regulations:—namely, that all powder for armaments is to be issued made up into cartridges; that all shells are to be filled by the Ordnance Store Department at the station; that filled shells may be examined in a tent or on the gun floor of casemated works; and that cartridges should be examined and the ammunition for instructional purposes made up in a central Royal Artillery Laboratory building.

The requirements of a fortress in these buildings are therefore one or more conveniently situated cartridge-filling rooms for the Royal Artillery, and a shell-filling room of sufficient size for the use of the Ordnance Store Department.

Cartridge-filling Room.—*Plate* XXXI.—A cartridge-filling room should be about 14 feet by 11 feet 6 inches in internal dimensions. It should have attached to it a shifting room, about 10 feet long by 5 feet wide, and an "outer cartridge room," which may be about 9 feet square. The rooms should be well lighted. There should be two hatches for the passage of powder barrels and cartridge cylinders; one in the outer wall of the filling room; the other between the filling and the outer rooms, forming the only direct communication between them.

The shifting room should have pegs for the clothes of four men.

The outer room requires no fittings except, perhaps, a form for the men to sit on.

The filling room contains a bench along the longest side of the room, another short one in any convenient position, a form for the men, and hooks for gauges. The long bench is divided into three parts: the right-hand portion has a beading round it and drawers underneath, and is used for keeping implements and filling cartridge bags; the centre portion is lower than the rest, and has a bracket above it for carrying scales for weighing powder; the left-hand portion is used for sewing up cartridges. The short additional bench is like this portion, and is used for the same purpose.

The work of filling cartridges is carried out in the following manner: the powder is passed in at the receiving hatch, and weighed out and filled into cartridge bags at the weighing bench. These are then sewn up at the sewing benches. One man at the weighing bench can keep three employed at sewing, being assisted by each in turn.

When the cartridges are sewn, they are passed into the outer room to be placed in their cylinders or cases, which are then lutened down.

Shell-filling Room.—Plate XXXI.—A shell-filling room for handling one shell at a time, should be about 11 feet 6 inches by 9 feet in internal dimensions, and should have attached to it a shifting room about 10 feet by 5 feet, and an "outer shell room" not less than 9 feet square.

There should be two hatches, "receiving" and "issuing," for the passage of shell between the filling and the outer rooms, and a hatch in an outer wall of the filling room for the admission of powder.

The filling room contains a bench with drawers, and a weighing bench with hook for scales, along the end of the room, like the right-hand and centre portions of the bench in the cartridge-filling room; also a form for the men to sit on.

In the centre of the clear floor space is a block of hard wood, with a conical hole in it for holding, point downwards, shells that have to be filled through a hole in the base. Over this block, when shell of

more than seven inches calibre may have to be handled, is fixed an eye-bolt, to take tackle for up-ending them. A small traveller would be preferable as it would be of assistance in moving the shell about the room, but it is not a necessity.

The outer room requires no fittings except a form and some hooks (say 6) for brushes used in cleaning the shell.

The work of filling shell is carried on in the following manner. The shell is taken into the outer room and cleared of grit; it is then passed in to the filling room through the receiving hatch, up-ended, the powder weighed out and filled into it, and the plug fastened hand-tight. It then goes through the issue hatch into the outer room again, where it is plugged and stencilled.

If it be desired to fill more than one shell at a time, additional space must be provided in both rooms, allowing 9 feet by 9 feet for each shell. One set of scales will do for operating on six shells at a time.

Construction of Cartridge and Shell-filling Rooms.—These rooms should be constructed of corrugated iron lined with wood, so that as little damage as possible may be done in case of an explosion. Covering the exterior with corrugated iron is also a prevention against fire.

Tackle for Up-ending Shells.—In shell-filling rooms, the overhead block for suspending shell must be carried on a beam 6 inches by 9 inches deep, supported on two uprights of extra strength, say 6 inches by 4 inches, in the framing of the walls. It may be necessary to place the beam askew to clear the windows. It will support 800 lbs., with a bearing of 9 feet in the clear.

If the shell-filling room be constructed for the manipulation of several projectiles at a time, this tackle should be carried on a traveller, passing over the various oak blocks in the floor. This may be of simple construction, supported on a series of uprights independent of the walls of the room.

A drawing of a shell-filling room accompanies I.G.F.'s Circular, No. 580, 23rd February, 1889.

8.—ADJUNCTS TO STORE MAGAZINES.

Examining Room and Cooperage.—As the *Ordnance Store Regulations* prescribe the examination of every barrel containing gunpowder before it is passed into a store magazine, it is necessary to provide an Examining Room for each, and also a Cooperage for small repairs to barrels, such as refixing hoops, and also for re-heading barrels when it may have been necessary to shift powder from one barrel to another.

These rooms should be near the magazine, but separated from it by traverses; they should be approached only through a shifting room, and the path between them and the magazine should be equally guarded. This path should be laid in wood or asphalte. The size of the rooms would depend on the storage capacity of the magazine and on the amount of use made of it, but they might both be 30 feet by 15 feet.

The examining room should be near the entrance to the magazine establishment, as all the barrels have to pass through it on arrival.

In the case of a water-side magazine, a small examining room should be placed at the end of the pier at which powder is landed, the whole of which should be under magazine conditions.

Empty Barrel Store and Magazine Store.—In large magazine establishments, in addition to the above, an empty barrel store and a magazine store for wadmiltilts and such articles are required.

9.—NOMENCLATURE AND LETTERING.

Nomenclature.—The official "Nomenclature of Artillery Magazines and Stores" will be found laid down in the *Equipment Regulations*, and in the *Regulations for the R.E. Department.*

Lettering.—The mode of "Lettering Emplacements and Accessories to Works of Defence" is laid down in the *Regulations for the R.E. Department.*

Cartridge and shell stores in coast batteries for heavy guns are lettered to show the calibre of those guns, for which the ammunition is placed in them. Recesses are marked with the number and nature of the guns with which they are connected, and so also are ammunition lifts both at top and at bottom. Lamp recesses are numbered from right to left throughout a work, both on the lighted side and on the lamp passage side of the recess, the two numbers being in all cases identical.

10.—DAMPNESS IN MAGAZINES.

Two Causes of Damp.—The causes of damp in a magazine are two: percolation of moisture through the roof, walls, or floor; and condensation.

The first is comparatively easy to deal with, and should never cause any serious trouble; the second is very difficult to stop entirely, and this is recognized to such an extent, that in all fort and battery magazines, the powder is stored in waterproof receptacles, either zinc cylinders or metal-lined cases, so as to be independent of the state of the magazine. It is nevertheless very necessary to do all that can be done to stop condensation, as otherwise the woodwork of the magazines and of the cases perishes rapidly. In store magazines, where barrels are used, it must be conquered entirely.

Percolation.—Foundations.—The percolation of water from below is stopped by a damp course of asphalte or cement rendering over the whole area of the building, walls and floors alike.

The foundations must be good, as if any settlement occurs, this will crack, and it will be difficult to get at it to mend it.

Walls.—Plate XXII.—The walls should be secured by building them hollow, and by rendering the exterior of the outer wall with cement, forming a drain at the base, and packing loose stones against the outside, which will aid the water in escaping.

These external drains are apt to become clogged, and the interstices between the stones get filled with earth, so that it is not safe to trust to them entirely, for which reason the double wall is desirable, but they should be used in order to keep the damp out of the mass of the building as much as possible.

The hollow space is usually provided by carrying the lamp passage round the exterior of the magazine chambers, which is an economical arrangement, and also allows of some inspection of the wall. If a simple air passage be provided, it is advisable to render the back of the inner wall as well as the outer one, and to provide a drain at its foot.

In a very damp situation it is best to have an air passage in addition to the lamp passage, and in addition to any hollow space left behind the brick lining to the magazine.

In building a magazine in rock which is sufficiently sound to admit of the arches being sprung from it, a double wall is unnecessary, or rather the rock becomes the exterior wall, as there is no fear of the space between it and the inner wall getting clogged. Rendering and forming a drain are then sufficient. In this case a damp course should be introduced at the springing, and connected with the covering of the roof to prevent water rising in the arch.

Asphalte on Roof.—The concrete covering the arches should be finished at a flat slope and asphalted, and drainage provided at the points to which the water will be directed.

If the asphalte be not covered with earth, the drainage will be arranged like that of an ordinary roof, care being taken to turn the asphalte over a coping so that the water may drip from it, and not soak into the wall; but as asphalte exposed to the sun and weather does not last as well as when it is protected by a covering of earth, it should have one whenever it is possible, and then drain pipes should be laid along the line of flow of the water, and carried down the walls.

It is not advisable to lay loose stones on the asphalte to form drains, as is sometimes done, since their points and angles may penetrate it and cause leaks.

The asphalte should always be turned over at the sides and carried a few inches down the walls, and if any ventilating shafts pass through it, it should be turned up round their sides.

Asphalte will be damaged by oil touching it. This it might be liable to in some situations from the drippings from gun carriages.

As with the most careful work there is a possibility of a leak occurring in a magazine, it should always be a point in designing it to consider how it would be got at for repairs. When a magazine is 40 feet underground, for instance, it is a serious business getting at the asphalte to mend it.

The most convenient arrangement is to have about three feet of earth over the asphalte of the roof; this is easy to remove, and is still sufficient to preserve it from the effect of the atmosphere, and from any casual injury. At the same time it must be admitted that this arrangement is easier to recommend than to carry into practice, but the principle should always be kept in view.

This consideration also bars the use of asphalte between two masses of concrete or masonry, where it is practically impossible to get at it, and where, I believe, it would be almost certain to permit of leaks; for large masses of concrete are very rigid, and what with expansion and contraction from heat, and the effects of very minute settlements, fissures would be formed just as in rock, and would take no account of the asphalte, which it would not be possible to mend.

The position of a magazine is usually fixed by considerations of security and convenience, and is not always in the driest spot that could be found. There is a magazine, for instance, in one of our works which was placed in such a position that the beds of rock

sloped down towards it from the parade of the fo so that the water falling on the parade ran down to the magazine. It was insufficiently drained at first and was very damp, but is now all right. In such a case extra precautions must be taken to carry off the water.

Condensation.—Condensation is the real enemy that has to be dealt with in trying to get dry magazines. It follows inevitably from the use of the great masses of earth and concrete with which we are compelled now-a-days to cover our magazines, that the interiors become like caves, which are almost always colder than the outer air; and consequently when any fresh air is admitted from the exterior it deposits some moisture on the walls and fittings. This may go on accumulating till the floor is slippery, and the skidding and other wood work soaked, so that in a few years it all perishes.

Remedies for Condensation.—Now the remedy for this is best found by noting what magazines are dry, and seeing what common peculiarity they possess which makes them so, and on this point I am convinced from inspecting a number of magazines, and hearing of many more, that the dry ones are those which are capable of thorough ventilation, and which have a non-conducting material such as brick for the inner surface of their walls; and that the dryness of similar magazines is fairly proportioned to the amount of ventilation.

The old type of magazine, standing up like a haystack, with big windows in the end walls, such as the Venetians and others built in the Mediterranean, are excellent for storing powder in, and so are the large store magazines which we build at present in situations where they are secure from attack, and where it is possible to adopt a similar type. The worst magazines of all are big main magazines buried safe from all possible shot or shell, but ventilated solely by the door and two or three 9-inch pipes in the roof.

Ventilation.—These are the two extremes, and there are magazines of all degrees of goodness between them; degrees depending mainly on the amount of ventilation which they possess; even a good draught past the door will make a perceptible difference in the dryness of a magazine.

In advocating a large amount of ventilation for a magazine I do not wish that it should be continually going on; no good is to be gained by introducing a large volume of air laden with moisture if it can be kept out; it would of course lead to much condensation, and though the next dry day it would all disappear, and so the magazine would be, at any rate, occasionally dry, yet by judicious opening and closing of the ventilators a better result can be arrived at.

On this point the regulations for airing magazines which prescribe the reading of wet and dry bulb thermometers, so that there may be certainty that dry air is being admitted, are good enough in theory, but they often fail of their effect; partly, no doubt, because they are not in all cases intelligently applied by the master gunners and magazine men who have to carry them out; partly because they do not recognise the fact that when a magazine is dry it is best to leave it so, and not to spoil it by introducing fresh air; and in many cases (what might well be avoided) because the ventilating arrangements of the magazines are so defective that hardly any air can pass through them. The opening or closing of the ends of a few 9-inch pipes can produce next to no effect on the mass of air in a large magazine; a feeble flow may result close to the pipe, but the amount of dry air introduced will be quite inadequate to take up, in any limited time, all the moisture deposited in the interior, which remains perfectly damp, unless there is a continuance of dry weather.

It is therefore necessary to have large ventilators which shall be capable of being readily opened and closed by the magazine man, according to the weather; and the openings into the magazine should be so placed as to ensure a thorough current of air passing through the magazine when they are open.

While these large ventilators should be provided, as remarked before it by no means follows that they should be often used. Indeed, I believe that this, or some similar rule, would be the best to make: that when a magazine is dry, the ventilators should be kept closed; if it becomes damp, through being opened for use, or from any other cause, they should be left open till it becomes dry again, and then closed as before.

Ventilating Arrangements of Store Magazines.—The driest magazines are those large store magazines which are independent buildings not covered up with earth, and mainly ventilated by large window openings in the end walls. There should be one opening over the door and, perhaps, one on each side of it out of reach of the ground, and these openings should be provided with close fitting shutters with spring latches, arranged so that they can be opened by a cord from the floor. The shutters should be so framed and pannelled that no shrinkage of the wood would leave any cracks through which burning particles might be able to pass, in the case of a fire any-

where near. Formerly all doors and shutters of magazines were covered with copper to prevent the possibility of such an accident.

In order that the door may be left open when the magazine is being aired, there should be an inner open work door covered with copper wire netting, which can be shut to prevent any of the men employed in the magazine enclosure entering it, except on duty.

Small ventilating openings can be also made in the side walls at the floor level; these should be bent so as not to lead straight into the magazine, and should be provided with shutters.

Shutters to Ventilators.—Before going any farther it will save some repetition to say that all ventilating openings about magazines should be provided with close fitting shutters, made either of wood or iron, so placed that they can be conveniently got at to be opened and closed according to the weather.

They should also be all lettered so that it may be known at once where they come from, whether from the magazine chambers themselves, from the lamp passages, or from an air passage.

Ventilating Arrangements of Large Fort and Battery Magazines.—In large fort and battery magazines, and in cartridge stores such as are in coast batteries, and which are usually completely buried, the magazine chambers, as a rule, have an entrance passage on one side, and a lamp or air passage round the other three. For purposes of ventilation, the entrance passage should be treated as part of the magazine chambers, and the lamp and air passages separated from them.

The point to attain is that there should be a thorough change of the air when the ventilation is in operation; it should not be allowed to stagnate at one end of a chamber. The ventilating shafts should therefore start from the end opposite the door.

Ventilating Shafts.—The 9-inch glazed earthenware pipes which are often used are too small, and condense moisture on their glazed surface, which runs down into the magazine.

A better form, where there is room to carry it out, is a brick shaft, about 2 feet 6 inches square in section, carried up from the side of the arch and along in the spandril to any point where it can conveniently turn up into the outer air. At the outer end it would be finished with louvres and shutters, or a trap-door, care being taken to have the openings between the louvres equal altogether in area to the cross section of the shaft, so that the air may move in or out freely.

The shaft should not be taken directly into the magazine, but should be bent once or twice in its course, and iron bars should be built in across it, somewhere near the top, where they can be got at and painted.

A shaft of this nature has been tried on a large and damp magazine with excellent results.

The entrance passage can be ventilated in the same way, but usually will get air enough through the door-way and cartridge lifts; the latter make capital ventilating shafts.

Ventilating openings should be brought out into the open air at different heights, so as to induce a current through them. It should be remembered that as the temperature inside a magazine will usually be lower than that outside, the flow of air will generally be down the ventilating shafts and out at the door. Extracting cowls fitted to the shafts will therefore impede rather than help the ventilation.

Lamp passages are ventilated in the same way as magazines. One shaft at the end opposite the entrance is as a rule enough, unless there are many lamps, but there should in all cases be one shaft at the extreme end, or that becomes a damp corner.

If there are any air spaces, they should be in communication with the lamp passage or with the outer air direct, but not with the magazine passage or chambers.

It occasionally becomes necessary to have recourse to artificial or forced ventilation, instead of trusting to the natural movement of the air; this is the case, for instance, at Spitbank Fort, Portsmouth, where the lamp passage is small and contains a large number of lamps, so that it would soon become unbearable when they are all lighted, if the air were not constantly changed. This is done by using Haworth's rotating ventilators fixed to shafts in the roof, which draw the air up through 9-inch pipes.

As this lamp passage is not external to the cartridge stores, but is merely the upper part of the magazine passage divided from it by a floor of slate slabs, it is not necessary to separate the ventilation, consequently the extracting pipes from the cartridge chambers are led into the lamp passage, and thus the air from the cartridge chambers is extracted through the lamp passage. These ventilators are closed by metal doors, where they issue from the magazine and lamp passages.

Ventilating Arrangements of Small Magazines.—The principles of ventilation for small magazines are the same as for large ones: 9-inch pipes can be used for the shafts, as they will be large enough in most cases.

The ventilation of expense ammunition stores requires to be considered with reference to each particular case, as the stores are put in all manner of places, not only opening on to parades or terre-pleins of works, but also off casemates and galleries underground which may be always dank with moisture. It is not much good taking air from such a place into the stores, and either independent ventilation for them must be provided, or an attempt must be made to keep the galleries dry as well; the latter course is the best.

Water sometimes finds its way into magazines by rain getting into the lifts and ventilating shafts; therefore ventilators should be closed in damp or rainy weather, but as an additional precaution it is advisable to provide the exits with louvres, and in large ventilating shafts, to have some means of escape for any water that may enter them, so that it may not run down their whole length into the magazine.

Rain water which has fallen on an emplacement, or on the floor of a casemate, is sometimes driven across it by the wind, and so under the bottom of the doors of the lifts down which it runs into the magazine. A small step about one inch high at the top of the lift will stop this. A step is objectionable, but in such a case unavoidable. List or leather may be nailed on the bottom of the door.

For regulations for Ventilation of Magazines, see *Equipment Regulations*, and also *Magazine Regulations*.

Lining of Walls.—The material of which the inner surface of the walls, arches, and floor is composed is almost equal in importance to the ventilation.

It should be non-conducting and absorbent of moisture; brick is about the best thing to use in ordinary cases.

Captain Moore's method might be used in alterations to old works. "The operation is as follows:—Rake out the joints of the masonry carefully, and render ½-inch thick in pure Portland cement, leaving a key on its surface. Whilst still green, render it over again with cement and sand (1 to 1), ¾-inch thick, leaving a good key so as to retain the inner coating of hair mortar, which should be applied as soon as the cement will stand it."

The necessity of attending to this point may be illustrated by the following example of a cartridge store: it was brick-lined except where a lift from the serving room above was carried through the arch, which at that point was strengthened by the insertion of a block of hard limestone; the store was fairly ventilated, and was consequently dry, except where the block of limestone occurred;

this was dripping wet, and the flooring underneath was wet with the water that had fallen from it. If the inside of the store had been built of this stone it would have been impossible to use it for ammunition.

Air Space.—An excellent non-conductor of heat is air, and an air space behind a brick wall assists materially in preventing its being chilled by the masses of concrete and earth by which it is surrounded.

An air space also forms a barrier to any leakage which may have penetrated the outer walls.

The good effect of an air space may be increased by admitting warm air to it; this air will communicate some of its heat to the walls, and will thus render the cool dry air which alone should be admitted into the magazine much less likely to deposit any moisture.

In order that this may be done it is necessary to keep the ventilation of the magazine and of the air space entirely separate; they should have separate ventilating shafts, and there should be no communication by air bricks in the walls or otherwise. It is probable that only in large establishments will the proper alternate opening of the ventilators of the magazine and of the air passage be carried out, but no constructive obstacles should be put in the way of its being done; even if it is not done the air space is useful.

A practical example of the benefit of the air space may be quoted: in a row of Haxo casemates, between the guns, were a shell store and a cartridge store; they were exactly similar in size, situation, and construction, except that the cartridge store had a lining of brick, with an air space behind it 4½ inches wide, communicating with the outer air through perforated bricks, while the shell store had none.

The shell store was damp, the cartridge store was dry.

This was striking, but a careful examination of them failed to bring to light any other cause for the difference besides the air space in the cartridge store.

As expense stores may have to be opened in all weathers for the service of the guns, and damp air may thus be admitted, it is of almost more importance with them than with store magazines to have a non-conducting material for the walls, and it is therefore best always to build them with a brick lining, having an air space behind it, communicating with the exterior through air bricks, which need not be provided with shutters.

A Non-Conducting Coating.—Any metal work in a magazine, such

as a roof girder or a lamp tube, soon gets beaded with moisture if there is any quantity in the air; this can be remedied by covering it with what is called cork composition, which is powdered cork dusted on to a coating of red lead and oil.

Cork Composition for Covering Floors of Magazines.—"With a view to diminish the condensation which takes place on the surface of asphalte or concrete in magazines, the surface can be covered with a mixture of four parts of Venetian red to one part of red lead, made thoroughly into a stiff paste with Stockholm tar. This material should be laid with a trowel to the thickness of one-eighth of an inch, and while wet should be covered with powdered cork, sifted over it to a thickness of three-eighths of an inch, and pressed down with a float and roller." The powdered cork can be obtained from any large cork dealer (Messrs. Jeune & Co., 4, Idol Lane, City, E.C.).

It is an excellent material, and is used both by the War Office and the Admiralty. It is much used for covering the smooth surface of asphalte floors, which condenses moisture a great deal. In this case it is necessary to protect it by batten flooring laid over it, so that it may not be rubbed off by the traffic. It might prove a good thing to cover all the walls and arches of a damp magazine with cork composition as well as the floor, but this has not yet been tried.

Summary.

We may now sum up the points necessary to be attended to in order to have a dry magazine.

The foundations must be perfect, so that there shall be no settlement.

There should be a damp course over the whole area.

The exterior wall should be hollow except sometimes in rock. It should be rendered outside and the foot drained.

Sometimes the interior wall should be rendered and drained also.

The concrete over the arches should be asphalted, and drains laid to carry away the water coming off it.

The arches should have a damp course at the springing.

The interior of the magazine should be of some non-conducting absorbent material, say brick, for the walls and arches, and cork composition for the metal work and sometimes for the floor.

It is a very good thing to have an air space behind the brick lining both in walls and arches.

The ventilation should be as free as possible when it is acting, but should be very seldom used.

The ventilation of the magazine chambers and of the air passage should be entirely distinct.

The magazine should be in such a position that it may be possible to get at the exterior to repair it.

11.—LIGHTNING CONDUCTORS.

All powder magazines and main cartridge stores should be protected by Lightning Conductors. Full instructions as to their application were issued with *Army Circulars* dated 1st November, 1887. The following are the main provisions laid down:—

Lightning rods should be about four feet high, and spaced at intervals not exceeding 50 feet, so that no point of the building to be protected is more than 25 feet horizontally distant from a lightning rod. They should be connected together by conductors carried over the ridges or other salient features, and in the case of underground magazines these conductors should be buried in the soil over the central line of the magazine. The conductors from the lightning rods should be carried to the earth connections by the shortest route outside the building, all sharp bends being avoided as far as possible.

As regards the earth connection, the essential point is to provide the best which can be obtained in the *immediate vicinity* of the magazine or building to be protected. In order to guard against accidental defects, at least two "earths" should be provided. "Earths" in fresh water, or in permanently damp soil, should offer at least 18 square feet of external surface; those in the sea should have a surface of five square feet under water or in wet sand. When the permanent water is deep, surface earths are required in addition around the building, and when the depth is considerable, two or more conductors may be connected to one and the same earth. Iron water-mains form the best earth connection. Where these do not exist, a coil of the conductor itself, buried in permanently damp soil, is preferable to an earth plate, as it obviates the necessity for any joint underground. A layer of coke, or smith's ashes, round the conductors and the earth, materially assists in improving the earth connection in dry weather, owing to its superior conductivity and its power of retaining moisture. In extremely dry or rocky sites the best plan to adopt is to bury several hundredweight of old

iron in a mass of coke at the foot of the "earth" coil, and to drain the surface water into it.

All external and internal masses of metal, such as gutter and down-pipes, sheeting on doors and windows, drying apparatus, etc., should be connected to the system of conductors.

Copper tape, 1 inch by ⅛-inch, procurable in lengths up to about 350 feet, and having a conductivity of at least 95 per cent. of that of pure copper, is the best material for lightning conductors, but, in exceptional situations, where copper would be liable to be stolen, galvanized iron wire ropes, weighing 8 lbs. to the yard, may be used.

Metallic continuity must be ensured at all the connections by perfectly fitting screwed joints or clamps. Solder should never be used, except for the repair of old conductors. When connecting copper conductors to iron or other metals, the greatest care must be taken to protect the surfaces in contact from galvanic action, by means of tarred tape or cement.

Conductors should not be insulated from the buildings to which they are attached, and provision should be made at intervals for expansion and contraction by means of small loops in the conductor.

Lightning conductors should be periodically inspected. In most cases, where care has been taken to ensure reliable earth connections, a careful visual examination by a competent mechanic is all that is necessary. In the case of old conductors, however, electrical tests of the continuity of the conductors and of the resistance of the earths, are necessary, but when the nature of the underground joints and earth connections are not recorded, it is advisable to have them dug up and examined, and, if necessary, improved.

It should be borne in mind that a faulty lightning rod is a distinct source of danger, inasmuch as it tends to invite a discharge, while the resistance at a defective joint or earth may cause a portion of it to seek another path disruptively through the building. A lightning rod is worse than useless unless every condition of efficiency is fulfilled.

Permanent Fortification For English Engineers

LEWIS

Chapter 4

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CHAPTER IV.

1. Coast Defence Weapons.—2. Guns.—3. Effect of Projectiles.—4. Ships and Guns.—5. Nature of the Attack on Coast Batteries.—6. Objects of Coast Batteries.—7. Disposition of Coast Works.—8. Positions for Coast Batteries.

1.—COAST DEFENCE WEAPONS.

There are three classes of weapons with which ships can be fought from the land: guns, submarine mines, and locomotive torpedoes.

The system of defence of a place is not, as a rule, complete without the two first, although circumstances sometimes forbid the use of the second, but at present our subject lies more with guns than with submarine mines, which are treated of elsewhere; still the various qualities of both may be shortly summed up to show how they supplement one another.

Comparison of Guns and Submarine Mines.—The gun is always on the spot and can be used in all weathers, except in fog, while the submarine mines may not be laid in time, or may be affected by storms and currents, or the bottom may be unsuitable for them, or the channel too wide or too deep for their practical use.

The area over which the gun can act is considerable, while that of the mine is small.

The projectile from the gun can be directed at the ship, but the ship must come to the mine for the latter to take effect.

A mine can be actually used only once, while the gun can deliver many shots. On the other hand the mine will act against any ship, armoured or unarmoured; its effects are very great, and a mine defence is comparatively cheap when the channel is not too wide. Fresh mines could be laid during a siege.

Neither guns nor mines by themselves can be counted on to close a channel. Ships may run past guns, if there are no mines, without being hit a sufficient number of times to be forced to stop by the

infliction of serious injuries; while if mines are laid and not protected, a certain amount of time only is necessary for the enemy to remove them or render them harmless.

In places such as roadsteads or short harbours, where the attacking ships could not evade the guns of the defence, mines are superfluous, as they are not needed to keep the ships under fire.

In the defence of commercial harbours, which it is essential to keep as free as possible for traffic, mines are, as a rule, objectionable, as they tend to obstruct this freedom of ingress for merchant ships.

Locomotive torpedoes.—Of these there are two kinds, those controlled from the shore and those discharged from a torpedo boat. The former have a range limited by the necessity of steering them, and therefore of seeing the torpedo as well as the ship to be attacked. The station from which they are steered and sometimes the machinery for driving them must be protected. This usually involves their being near a supporting battery, but in favourable situations they can be worked in considerable security. As they can be steered they can command a large lateral arc like a gun. They carry a large charge, and are thus effective against all classes of ships. As they require a certain depth of water to float in, they are incompatible with submarine mines except ground mines fired by observation. They seem to be most suitably used in situations where submarine mines cannot be employed, where they would afford an alternative means of making an under-water attack.

Torpedoes fired from a boat have in connection with the boat an unlimited range, but owing to the certainty almost of injury to the boat they cannot be used in open daylight. In dim light, mist, or smoke, however, they would have great opportunities. The fear of them would have a great effect in preventing ships from anchoring, without doing which they can hardly hope to make good practice with their guns.

Zalinski Gun.—A weapon partaking of the characteristics both of the gun proper and of the locomotive torpedo is the Zalinski gun, which throws shells carrying large charges of high explosive by means of compressed air. Its range is not great, though much superior to that of the controlled torpedo, nor is its accuracy so good as that of a gun, but it has several valuable features. It has been said that it is equally dangerous whether it hits or misses, because if the shell misses a ship but bursts close by under water, it will act like a torpedo. The weapon makes no noise or smoke, and is, therefore, easy of concealment. It is about the same size as a large B.L. gun, and its emplacement would be about of the same dimensions.

Space would have to be provided for a magazine for the large shells, and also for an engine and boiler-house, and for the reservoirs of compressed air. There is probably a future before this weapon.

Coast Batteries merely Positions for Guns—It follows from the importance of the *rôle* that the gun has to fill that coast batteries are merely positions for guns, and the details should be arranged to give the gun the greatest possible efficiency.

It may be remarked that, of course, coast and river batteries are essentially the same, differing only in position, and the term "coast battery" is used as including both.

Before going into the details of the batteries, and the choice of positions, it is necessary to say a few words on the nature of the guns used, and of the ships that may have to be fought against.

2.—GUNS.

Table of Guns.—The tables which follow show the guns, both B.L. and R.M.L., which are at present mounted in English coast batteries, with their muzzle velocities and energies, and with other information likely to be useful.

The essential difference between the new type guns and the old ones is, that the former attain a high penetration by firing comparatively light shot with a high velocity. This high velocity is obtained, without overstraining the gun, by using large charges of slow-burning powder in a long gun. The length of the gun necessitates breech-loading as a practical matter of convenience.

Table of B.L. Guns.

Calibre in Inches.	16·25	13·5	12	10	9·2	8	6	5	4
Mark.			VI.	II.	IV.	IV.	IV.	IV.	V.
Length, total, in feet and inches	43′ 0″	36′ 1″	27′ 4¼″	28′ 6½″	25′ 10″	21′ 2½″	14′ 5·5″	11′ 7¼″	16′
Weight, total, nominal in tons	111	69	46	29	23	15	5	40 cwt.	26 cwt.
Weight of projectile, in lbs...	1,800	1,250	714	500	380	210	100	50	25
Energy, total, at muzzle, in foot tons ..	55,250	35,600	18,060	15,290	11,240	7,048	2,372	1,123	[illegible]
Velocity, muzzle, in ft. secs.	2,104	2,016	1,892	2,100	2,065	2,200	1,850	1,800	1,9[illegible]
Maximum charge in lbs.	960 S.B.C.	630 S.B.C.	295 Pm.[1]	300	170 Pm.[1]	125 Pm.[1]	42 P.[2]	16 S.P.	12 S.P.

Table for R.M.L. Guns.

Calibre in inches.	17·72	12·5	12	11	10	9	8	7
Mark.		I.	II.	II.	II.	V.	III.	IV.
Length, total, in feet and inches	32′ 8″	19′ 2″	15′ 2·5″	15′ 0″	15′ 0″	13′ 0″	12′ 0″	12′ 4″
Weight, total, nominal in tons	100	38	25	25	18	12	9	7
Weight of projectile in lbs...	2,000	820	614	547	410	258	187	115
Energy, total, at muzzle, in foot tons ..	32,710	11,820	7,000	6,547	5,356	3,643	2,323	1,943
Velocity, muzzle, in ft. secs.	1,548	1,442	1,288	1,314	1,379	1,440	1,384	1,561
Maximum charge in lbs.	450 Pm.[1]	160 P.[2]	85 P[2]	85 P.	70 P.	50 P.	35 P.	30 P.

Table of Lengths from Muzzle to Centre of Trunnions of B.L. Guns.

Gun.	Mark.	Length in Inches.	Remarks.
4-inch.	II.	81·7	
do.	III.		
do.	IV.	77·7	
do.	V.	77·5	
5-inch.	I., II.	97·2	
do.	III.	95·2	
do.	IV.	94·45	
6-inch.	II.	104·2	None as yet mounted in the land service.
do.	III.	113·6	
do.	IV.	114·5	
6-inch E.O.C.	V.	134·4	Only 7 in the service.
8-inch E.O.C.	VII.	150·6	Only 4 in the land service, and no other 8-inch B.L. gun.
9·2-inch.	I.	182·05	
do.	IV.	209·5	
do.	V.	213·0	
10-inch.	I.	229·0	
do.	II.	237·6	
do.	III.	237·6	
12-inch.	I.	231·65	

NOTE.—The largest guns are not made with trunnions.

Table of Lengths from Muzzle to Centre of Trunnions of R.M.L. Guns.

Gun.	Mark.	Length in Inches.	Remarks.
64-pr., 64-cwt., W.I.	I.	68·5	
" "	II.	70·25	
" "	III.	70·25	
64-pr./32-pr., 58-cwt. converted... ...	...	68·4	
64-pr./8", 71-cwt. converted... ...	...	64·5	
80-pr./68-pr., 5-ton converted	...	72	
7-inch B.L., 82-cwt.	...	74·7	
" 90-cwt., R.M.L.	I.	79·35	
" 6½-ton "	I.	80·75	
" " "	II.	81·25	
" " "	III.	81·25	51 made.
7-inch, 7-ton "	I.	89	
" " "	II.	92	
" " "	III.	97	
8-inch, 9-ton "	I.	86·45	
" " "	II.	87	
" " "	III.	82	
9-inch, 12-ton "	I.	90·55	
" " "	II.	90·0	
" " "	III.	90·0	
" " "	IV.	89·75	
" " "	V.	89·75	
10-inch, 18-ton "	I.	108·65	
" " "	II.	109·4	
11-inch, 25-ton "	I.	111·65	
" " "	II.	109·4	
12-inch, 25-ton "	II.	110·7	
" 35-ton "	I.	122·1	
12·5-inch, 38-ton "	I.	149·4	
16-inch, 80-ton "	..	222·6	
17·72-inch, 100-ton "	...	260·34	

3.—EFFECT OF PROJECTILES.

Before describing the various forms of gun emplacements and batteries, it is necessary to give some information on the effect of heavy shot and shell on iron, masonry, earth, and other materials, on which these forms depend. This is, however, by no means so complete as might be wished.

Penetration into Iron.—Penetration into iron constructions is dealt with by Colonel Inglis in various articles in the *R.E. Professional Papers*, more especially in that published in July, 1880, which also treats of the type of long guns which were then being introduced into use by all nations.

The "Notes of Lectures on Iron Fortifications," delivered by him at Chatham, in February, 1875, form a summary of information up to that date.

Lord Brassey's *Navy Annual* contains a section by Captain Orde Browne, on "Armour and Ordnance," which deals with armour mainly from the point of view of ships, and of the power of guns to attack them with.

The Naval *Gunnery Manual* is another good work of reference on this subject.

It is unnecessary here to go into detail on this subject, as minute knowledge of the effect of projectiles on iron structures is not required in order to understand their value in action. It is, however, necessary to know generally the power of guns, and a rule may be given which is approximately correct and easily remembered; it is that against a single wrought-iron unbacked plate, a shot will perforate one calibre in thickness for every 1,000 feet velocity. Thus a 10-inch shot with 1,500 feet velocity will perforate a 15-inch wrought-iron plate; with 2,000 feet velocity it will perforate a 20-inch plate, and similarly for other calibres Another useful rule is, that a common shell will perforate a plate half-a-calibre thick; thus, a 10-inch common shell can be put through a 5-inch plate.

To arrive at the strength of a steel-faced plate, an addition of one third to its thickness will give the thickness of a wrought-iron plate of equal strength to resist a single blow. The comparison even then is not quite correct. The steel-faced plate resists in a different manner to the wrought-iron one, and requires rather to be smashed up than to be perforated. Its resistance sometimes rises to nearly double that of a wrought-iron plate of equal thickness, and sometimes falls to the same amount.

Displacement of Shields.—As affecting the masonry construction, however, one effect of a shield being struck by a projectile may be mentioned. This is that there is a tendency for it to be moved back bodily, and this must be resisted by the disposition of the stone-work or concrete around it, as the weight of the shield alone is insufficient. To attain this end the base plate of the shield frame is either let into a floor of granite blocks, or held down by powerful bolts 6 or 8 feet long, and the masonry on each side and in the arch, if there be one, is brought close up to the frame, so as to prevent any angular displacement or lateral movement. See *Plate* XXXIII. If an iron roof be used, the girders hold the top of the shield in place, and their rear ends are, if possible, abutted against some solid building, such as the end of a casemate. See *Plate* XXXIV.

It is of extreme importance to prevent any movement of the shield for two reasons; one, that a very little may seriously diminish the lateral arc of training of the gun, and another, that any backward movement might displace the racers, and thus prevent the gun traversing.

"Grüson" Cast-iron Armour.—Cast-iron armour made by Grüson is largely employed on the Continent, but has not been used in our service. It has the great advantage that it can be cast in a form suited to glance off any shot striking it. Roughly speaking it has to be made twice as thick as wrought iron armour to withstand the same gun. It has to be shattered by the energy of the projectiles striking it, and cannot be penetrated like a plate, and being thick will hold together even when badly cracked. A portion of a Grüson turret, 42 inches thick, was shattered at a short range by four rounds from a 12-inch gun, about equal in power to our 46-ton gun. It is most unlikely that four rounds would strike the same section in action.

Penetration into Masonry: Shoeburyness Experiments in 1865.—For several years the principal information that we had concerning the penetration of heavy projectiles into masonry was derived from the experiments carried out in 1865 at Shoeburyness; an account of which, by Colonel Inglis, will be found in the *R.E. Professional Papers*, Second Series, Vol. XVIII.

Two casemates of brick, faced with large granite blocks, were built and provided with iron shields, one shield being 12 feet by 8 feet, and the other 6 feet by 6 feet.

The piers were 14 feet thick, and the centre one was 15 feet wide. This work illustrated two forms of casemate, both of which have

been used: the one with the large shield very extensively. It is similar to that shown in *Plate* XXXIII.

A few of the results of the firing will give an idea of the amount of penetration of the shots and of the nature of the other effects produced by them, but the whole account is instructive.

Effect of Firing against Centre Pier.—A 9-inch steel shot fired at the centre pier penetrated nine inches into the granite, loosened the joints, and cracked the brickwork and concrete.

Another 9-inch steel shot penetrated 18 inches, broke off some of the face, and cracked two blocks and the brickwork in the arches.

Another 9-inch cast iron shot struck near the last, knocked out the granite to the depth of 2 feet 1 inch, cracked and displaced two other blocks, and cracked the brickwork a good deal.

The cracks, however, were not so bad but that a 22-ton gun could be fired from off the arches without enlarging the cracks. The pier was finally destroyed by 22 blows, 12 of them being from a 10-inch gun.

Effect of Firing against Arch.—A 10-inch cast iron shot fired at the lower arch ring over the 12-feet shield, injured severely four of the stones and cracked and lifted others.

Another 10-inch steel shot struck the springer of the arch, injured one arch stone besides, and brought down parts of two other blocks. The work near was much cracked.

The arch was completely destroyed by 10 shots, of which four were from a 10-inch gun, three from a 9-inch, the remainder 7-inch and 8-inch.

Velocities of the Projectiles.—The shot in these experiments were fired with velocities such as they would have at ranges of from 600 to 1,000 yards. The usual velocities of shot have since been much increased, so that guns of the same calibres as those used would now hit very much harder at these ranges, and the effects would consequently be far greater. A comparison of the energies of the projectiles shows that it is probable that greater results would be obtained from the auxiliary armaments of modern ships.

Shoeburyness Experiments in 1877.—In 1877 the experiment was made of firing a Palliser shell, without a bursting charge, from a 38-ton gun against a granite-faced wall, which is described by Colonel Inglis in the *R.E. Professional Papers*, Occasional Papers Series, Vol. I.

The wall was part of the old experimental casemates, and had been already somewhat shaken; it was about 16 feet by 12 feet, by 16 feet high. The range was 70 yards, the charge of the gun 130lbs. P., the striking velocity of the projectile about 1,405 feet per second, and its energy 10,947 foot-tons.

It struck fair on a granite block and immediately turned to the left, passing through 5 feet 6 inches of granite and 5 feet 6 inches of brick and Portland cement concrete, being found lying on the floor of the casemate.

The wall was completely wrecked; it seemed to have been lifted and shaken; the stones were all out of place, and masses of the brickwork thrown down.

Many years after the 1865 experiments, when the power of guns had much increased, further information on this subject was sought for.

Dungeness in 1880-1.—A 10-inch R.M.L. gun, with a charge of 95lbs. P., and a 408lb. Palliser plugged shell, at a range of 145 yards, obtained a penetration of 17 feet into a mass of cement concrete. The concrete was composed of 6 parts beach shingle, 1 sand, 1 Portland cement. The muzzle velocity would be 1,510 feet-seconds, and the muzzle energy 6,364 feet-tons.

A 6-inch 80-pounder B.L. gun of four tons, with a charge of 34lbs. P., and striking energy of 1,989 foot-tons, at the same range, obtained a penetration of 12 feet 6 inches into the same target.

Shoeburyness in 1883.—The 80-ton R.M.L. gun was fired against masonry, against masonry strengthened with armour, and against a mass of concrete. A battering charge of 450lbs. P. was used, and a projectile weighing 1,700lbs. The range was 200 yards, and the striking velocities between 1,568 and 1,584 feet per second. The striking energies were about 30,000 foot-tons.

The result against the masonry was most destructive. The wall was faced with large granite blocks, averaging 3 feet 9 inches thick. Portions of four courses of these were hurled aside, the disruptive effect being very great. The shot penetrated 17 feet 6 inches before it turned at right angles against an inner granite wall; afterwards passing through 10 feet of concrete and brickwork before finally coming to rest.

The armour was sufficient to guard the masonry from great injury, both where a 12-inch compound plate was used, and where two 8-inch wrought iron plates were employed, but this protection is very costly.

In the Portland cement concrete, which was 40 feet thick, the shot penetrated to a depth of 34 feet, and the disrupting effect was

much less than in the case of the granite. The mass of concrete was cracked, but none was thrown aside, though about 70 square feet of the surface was flaked to a depth of two feet. The shot struck about six feet below the top.

Shoeburyness in 1884.—The 12-inch 43-ton B.L. gun was fired against the same structure as the 80-ton gun, it having been repaired during the interval.

Target: a wall composed of 14 feet of granite and Portland stone, then two feet of Portland cement concrete, then six feet of brick-work. Weight of shot, 715lbs. Striking velocity, 1,804 feet per second. Striking energy, 16,000 foot-tons. Effect: the granite was much displaced and shattered; penetration, 11 feet 4 inches; two slight cracks in brickwork.

Target: a mass of Portland cement concrete. Shot, 715lbs. Striking velocity, 1,524 feet per second, equal to that due to a range of 2,000 yards. Striking energy, 15,000 foot-tons. Effect: a penetration of 24 feet, with star cracks round the hole, and a flake off the front 7 feet 9 inches by 5 feet 3 inches by 2 feet deep.

The protection given by the two 8-inch W.I. plates brought down the penetration into the granite to 5 feet 10 inches, and reduced the displacement to a small amount.

These experiments are sufficient to show the necessity, in the face of modern artillery, of abandoning the use of vertical masonry in situations exposed to the fire of heavy guns.

The disruptive effect on granite is so great as to neutralize its value in giving a hard surface. It was thought that an outer skin of iron would assist materially in checking disruption, and this has been tested with the 43-ton B.L. gun. Concrete 17 feet thick, faced with three inches of iron, was placed in front of the granite wall. The result was not satisfactory as the concrete was disintegrated.

Results obtained from Alexandria.—The maximum penetration of blind shell, 9-inch or 10-inch, into the soft rubble escarp of Fort Adda was from 8 to 9 feet. A 9-inch Palliser burst with 4-feet penetration. A 16-inch common shell burst with 8 feet 6 inches penetration, and made a crater about 10 feet in diameter at the face of the wall. This was one of the best results obtained. The shell struck near the base of the wall. Range about 1,500 yards.

At Fort Pharos the 10-inch shell, common and Palliser, penetrated the 8-foot rubble walls of the casemates and burst inside.

Formula for Penetration.—From the results of practice on various occasions, a formula for penetration into concrete has been arrived at, which gives very fair results. It is $P = \frac{E \times \cdot 3}{D^2}$ where P = depth of penetration in feet, E = energy of shot on impact in foot-tons, and D = calibre of shot in inches. In other words, the cubic contents of the hole formed are assumed to vary as the energy expended.

This formula suits M.L. guns firing heavy projectiles with a comparatively low velocity, and also the 12-inch B.L.; but when applied to the round from the 6-inch B.L. gun quoted above, the constant ·3 is too high; ·2 is suitable. There have been no experiments with the 8-inch, 9·2-inch, or 10-inch B.L. guns, which would enable one to test the value of the constant for them.

From the effect of the round from a 38-ton gun fired at Shoeburyness in 1877, it would appear that the constant for a granite-faced wall should be ·15; that is to say, that the penetration is about half that into concrete; and from an experiment with a 12-inch B.L. gun in 1884 that it should be ·1; but the data are not sufficient to found a law upon.

It is to be borne in mind that this formula only applies when the mass fired at has a vertical or nearly vertical face, and the energy of the projectile is wholly devoted to penetrating it. If formed with an inclined surface the shot will be deflected on striking it.

Penetration into Earth.—For determining the penetration into earth we have the following experiments:—

Shoeburyness in 1865.—At Shoeburyness in 1865 some shots were fired into a butt of stiff marsh clay.

The 13·3-inch R.M.L. gun gave a mean penetration for 23 shots of 36½ feet; the maximum penetration was 50 feet.

A 9·22-inch R.M.L. gun gave a mean penetration for 43 shots of 32 feet; the maximum penetration being 40 feet.

Woolwich in 1880.—During the trials of the *Thunderer* 12-inch R.M.L. gun at Woolwich in 1880, service shot were used, and the amount of penetration into the butt noted. The maximum was 55 feet. The material of the butt was sand. This is the best resisting material—as clay is the worst—so that the two sets of experiments can hardly be compared together.

Erratic Course of Shot.—It is to be noted that the shot when recovered were found pointing in all directions, and they had not taken a straight course, but were deflected up, down, and sideways, apparently in a very capricious manner.

It must not, therefore, be assumed that because a building is protected from a direct blow by a mass of earth, that it is therefore secure, as a shot may turn towards it. On the other hand, this tendency to turn may be encouraged and utilized by forming hard layers of stone or concrete in a parapet in a manner calculated to deflect the enemy's projectiles in the direction in which they will do least harm.

If casemates or concrete masses are finished with sloping surfaces under an earth covering, they are more likely to escape injury than if they ended with a vertical wall, as the shot would probably glance and turn upwards.

Penetration into Earth.—Results obtained from Alexandria.—The most surprising result of all obtained from this action, was that no projectile penetrated more than 20 feet of sand—not even that from the 80-ton gun. All those that struck parapets of greater thickness turned up and came out. In the trials of the *Thunderer* gun at Woolwich, in 1880, the shot struck the butt only 6 feet below the upper surface of the sand, and yet kept their course, or even turned downwards. It would seem, therefore, as if a shot behaved differently at a long range and at a short one.

The results at Alexandria showed that the protection afforded by a sand parapet is much greater than had been previously supposed. Also that the tendency of the shot to deflect should be assisted by the use of easy slopes in the parapets. This has been confirmed by experiments with medium guns.

Some Italian experiments in 1881 with a 10-inch gun, at a range of 1,000 metres (equal to nearly 1,100 yards) gave a penetration of 24 feet into earth and 20 feet into sand. This is an interesting result, as it was obtained at a range which might be used in action, but I do not know the form of the butt.

Power of 80-ton Gun.—Some idea of the power of modern guns may be formed when we consider that the energy of the shot from the 80-ton R.M.L. gun, at a range of 2,000 yards, is just about equal to that of H.M.S. *Rupert* ramming at a speed of 10 knots an hour.

Effect of Heavy Shell.—Of the effect of heavy shell fired from armour-piercing guns against masonry we know little, but it is perfectly certain, that if the shell have time to penetrate before exploding, the effect will be much greater than with solid shot. The use of a delay-action fuze, one, that is, which will not ignite the bursting charge until a certain time has elapsed after the shell has struck, will increase the effect, and so also will the use of high explosives.

In 1881, at Dungeness, some cast-iron common shell, loaded with $20\frac{1}{4}$-lbs. of gunpowder, were fired from a 10-inch R.M.L. gun against a concrete mass. Their mean penetration was 8 feet 9 inches, and the effect enormously destructive, forming large craters from 10 feet to 14 feet in diameter, starting and shaking the material over great distances, and throwing down the concrete in masses.

Experiments at Dungeness have shown that the effect of 8-inch shell against concrete and brickwork is very great even when thrown with a low velocity. This is an effect of burst, not of penetration.

Shell against Earth.—The magnitude of the effect of a shell against earth, depends entirely on whether it explodes in contact with it or not. If the slopes are flat, so that the projectile will glance before bursting, very little will result, whether it be charged with gunpowder or with a high explosive.

A 6-inch common shell, bursting in a clay parapet, has removed as much as 22 cubic yards at once, but ordinarily it would only move 5 or 6 yards.

In 1881, two common shell, from a 10-inch R.M.L. gun with a $20\frac{1}{4}$-lbs. bursting charge, cut through a 30-feet parapet built of clay; but three similar rounds against one built in sand only got half way through.

The same result was obtained in 1885 against a clay parapet with a 9·2-inch B.L. gun firing common (cast-iron) shell. Against a light loam parapet it did not do so well as the 10-inch R.M.L. against sand; but there was a difference in the exterior slope (15° instead of 45°) which is sufficient to account for it.

Shell Bursting in Parados.—Some experiments were carried on in Italy, in 1881, to determine the effect of the shells from various guns bursting in an earthen parados.

It was found that where field guns only attack, no bursts back from parados need be feared.

That with medium guns and howitzers up to 6 inches calibre, the parados should be constructed 60 yards back from the line of defence. That with heavier guns this distance should be 90 yards. The shells from the medium and heavy guns threw up a quantity of earth, and sometimes splinters and bases of shells.

When the shells had percussion fuzes, 2 feet of penetration before bursting checked splinters, but earth was thrown up by shells with time fuzes exploding at a depth of not more than 7 feet.

Experiments quoted by General Brialmont in *Fortification à Fosses Secs* confirm the Italian results, in so far that they show that bursts back are not dangerous from the projectiles of field guns; but no guns were tried on that occasion so large as 6 inches in calibre.

It should be noted that these experiments were carried out against earth unmixed with stones.

The effect of the shells would be much increased by the presence of stones in the earth, or, in the winter, by the frozen surface soil.

In the *Manual of Siege and Garrison Artillery* it is stated that shells are liable to ricochet on striking earthwork at angles under 20° or 1 in 2·75. It is therefore desirable to make the slopes of parados flatter than this.

Effect of Shrapnel.—Against open batteries ships might possibly fire shrapnel with a view to silencing the guns. The effect of shrapnel shell is very great if burst at the right point; to do this, however, requires accuracy of aim, with a different elevation to that for other projectiles, and a good time fuze, and the conditions are hard to satisfy on board ship; nevertheless, its searching effect, the area covered by the fragments, and the size that some of them may have, combine to render shrapnel the most difficult projectile to guard against in barbette emplacements. Judging, however, from the results of experiments at Inchkeith in 1884, and at Portland Bill in 1885, the difficulty of using shrapnel on board ship is sufficiently great to render the danger likely to come from it a slight one in practice. If it be wished to estimate the searching effect of shrapnel, it will probably be sufficiently accurate to add 5° to the angle of descent of the shell.

Medium Guns on Board Ship.—All ships, even ironclads, carrying heavy guns, are provided with a number of smaller guns, 6-inch and under, for firing at unarmoured vessels or torpedo boats. These would certainly be used against batteries as long as they could be worked, which might not be long, for they are in no case mounted behind thick armour. Against barbette batteries it might be expected that they would be very effective from the rapidity of their fire compared with that of the heavy guns, but those used at Alexandria appear to have produced but little effect.

They would probably fire shrapnel or common shell, and the character of the results may be arrived at by observing the performances of similar guns against land works.

Q.F. guns, such as the 4·7-inch, would class with these guns.

Machine Guns.—These are numerous in pattern; they fire an infantry rifle cartridge, and when correctly laid are comparable in the effect they produce to a number of men firing rapidly. It appears, however, both from the fighting at Alexandria, and from the experiments at Inchkeith in 1884, and at Portland Bill in 1885, that it is extremely difficult to direct them. In all these cases, while the bullets fired were numbered in thousands, the hits were only in tens or even in units. They are not, therefore, to be dreaded, except at very short ranges.

Quick-Firing Guns.—These are represented by the Nordenfelt and Hotchkiss. The smallest is the 1-inch bore Nordenfelt. It can penetrate a $\frac{3}{4}$-inch steel plate at 200 yards range. The smallest size of the Hotchkiss is $1\frac{1}{2}$-inch bore, and fires a shell. The force of the projectile is sufficiently great to injure the fittings of gun-carriages, such as sights and elevating arcs, and possibly to burr up the metal of the slides if they were to strike it, so interfering with the running up of the gun.

As to rapidity, the Nordenfelt 4-barrel will give 100 aimed shot per minute; the Hotchkiss about 30.

As to accuracy, it is considered that experiments have shown that the attack of torpedo boats during day time in the open sea is rendered perfectly impossible by the use of these guns, and no doubt the number of hits to be obtained from them at ranges under 1,000 yards is considerable. A torpedo boat is a small thing to hit, a second class one being only three feet out of water, with 7ft. 6in. beam; when this can be constantly struck while in motion it might be thought that forts would get many bullets in the ports and about the guns, but experience up to the present seems to show that for chances of hitting them they rank with machine guns.

The effect of the Hotchkiss shells against men has been shown to be considerable in actual warfare.

The largest of the smaller class of Q.F. gun is the 6-pounder, which is capable of penetrating 3·2 inches of mild steel at the muzzle. The 3-pounder Q.F. is also extensively used. They might both fire twelve rounds a minute. As to accuracy, the 6-pounder made very good practice at Inchkeith, where at 1,000 yards three shells out of five hit a 10-inch gun which was being fired at. It showed what the weapon is capable of in skilful hands; but there is no reason to suppose that it would generally be more effective than others of its class.

In addition to all these the crews of ships, of course, have rifles.

4.—SHIPS AND GUNS.

List of War Ships.—A list of the war ships of the world, giving their dimensions and armament and other particulars, together with drawings of many of them, is to be found in the *Naval Annual*, by Lord Brassey, a work which has redeemed the English nation from the reproach which formerly rested on it that it had no list of war ships comparable to that of the French and Austrians. The Austrian *Marine Almanac* and the French *Carnet de l'Officier de Marine* are convenient little books and are handy, one of the few laudatory adjectives that cannot be applied to the *Naval Annual.*

Classification of Ships of War.—Ships of war may be classified for our purposes in the following manner:—

First class armoured ships.
Second class armoured ships.
Protected and unarmoured ships.

The first class ships may be taken as those with a maximum armour of not less than eight inches; the second class ships as those with a less thickness of maximum armour; while the protected ships are those with armoured decks only.

In order to penetrate the armour of the first class ships at long ranges for this kind of work, namely 3,000 yards, the heavier natures of gun must be used. For the second class, the smaller armour piercing guns, such as the 6-inch B.L. and the 9-inch and 10-inch R.M.L., are in most cases sufficient; while the unarmoured ships can be penetrated by anything. The protected ships are vulnerable above the water line, equally with the unarmoured.

Only the thickness of the armour-plating is taken into account in this classification, as most of the qualities which give a ship value for fighting at sea against other vessels are of no assistance to her when engaging a battery. Speed is of no account except for running past a battery; handiness may be of some service in confined waters, but will not render the task of the battery more difficult; steadiness of platform will be of some avail, but not much, as the fighting will most likely be in sheltered waters. Gun power is a matter of importance, but the power lies more in the accuracy with which the projectiles are directed than merely in their size. A 6-inch shell will do as much harm inside a gun emplacement as a 16-inch. Draught of water is of importance in many cases, though it will not serve as a basis for classification. Most armourclads are large vessels that could not venture into water less than five fathoms deep, but there are a number of turret ships, such as the French *Tempête* class, and the Russian, Dutch and American monitors, drawing less than 18 feet; there are two powerful turret ships belonging to Brazil which draw less than 12 feet, and the French have laid down some armoured gunboats of about the same draught.

What, however, has to be taken into careful consideration, is the arrangement of the armour on the vessels, and in this the older ships differ materially from those of more recent construction. In the earlier days of armoured ship building there was an attempt to protect the men and guns from heavy shells as well as to safeguard the flotation and machinery. Latterly, owing to the many demands made for efficiency in other directions, this has been given up; methods of mounting guns have come in which are incompatible with it, and as a consequence in most modern ships the heavy guns sometimes, and almost always the lighter ones, can be struck by the lightest shell.

Now, a ship whose guns have been silenced can do no harm to a battery, and consequently, as a rule, it is sufficient to provide an armament for the latter that can deal with the artillery of any ship that is likely to attack it. The exception would be in the defence of a channel when a ship might try to run by, and it would be necessary to injure her motive power; but this would be best done with submarine mines or locomotive torpedoes.

Modes of Mounting Naval Guns.—A brief account of the various ways of mounting guns on board ship will plainly be of service in deciding on the natures of the ordnance to be used in the coast batteries. In the earlier ships, guns of what would now be considered moderate armour-piercing power are mounted behind thin plating on the broadside. These were succeeded by thin turrets, and these two types have both been developed into similar forms with much heavier guns and thicker armour, the turret ship attaining a more advanced stage than the broadside on account of the facilities it offered for working very heavy artillery. Both types are included in both classes of armoured ships, the broadside vessels being represented by the *Dévastation* and her sisters in the French navy, and the turret ships being numerous everywhere. These earlier ships did not carry many light guns.

Breechloading rendered possible several new forms, some of which had long been in use in other navies than our own. They may all be included under the term "barbette," but give varying amounts of protection. They agree, however, in the one point that the gun is almost or quite exposed at the moment of firing.

Some barbettes are similar to those we are accustomed to on land, being protected up to a certain level by a parapet of iron, and being provided with a light steel shield, or hood, proof against the fire of small machine guns and shrapnel bullets. Loading is sometimes done with the breech end of the gun depressed.

In some cases the gun disappears for loading, as in the Moncrieff system. The Russians have adopted this method with the 50-ton guns of the *Tchesmé* class.

In the *Collingwood* mounting, as it is called in England, the slide is pivoted horizontally on its front end, and is supported at the other end by a powerful hydraulic ram. By means of this ram the gun, together with the slide, is lowered into the loading position, which is that of the gun at extreme elevation, and in the same way it is given the necessary elevation for firing. All the operations of loading are performed by hydraulics. Protection is given by a horizontal steel deck through a slot in which the gun works, revolving within a fixed armoured wall. Security, equal to that from a turret, is given by this method to the detachment, and to everything except the gun itself.

The smaller B.L. guns are mounted either on the broadside, in which case they fire through ports in thin steel plates; or on the upper deck with central pivots, in which case the slide carries a light steel shield for protection from frontal fire. The Q.F. guns are arranged in a similar manner.

It is to be noted that the thickest protection is in all cases reserved for the water-line, and is not given to the guns.

At the first introduction of armour plating the great object in view was to keep out the shells which had wrought such havoc in the Turkish ships at Sinope. Apparently the fear of them gradually diminished until the use of high explosives has revived it again. There are consequently signs of an increase in the amount of thin armour to be used about the guns. This is not likely to exceed six inches in thickness, on account of the weight involved, which is urgently required for so many other things; but it is as well to look forward to this amount being carried in the battle ships, and perhaps in the larger cruisers.

As to the methods in which the different classes of ships carry their guns, there will be found among the first class battle ships examples of every variety mentioned above. Among the second class ships, there are all of them except the disappearing and *Collingwood* mountings. The latter is not required except for very heavy guns, which these ships do not carry. The unarmoured and protected ships have their guns either on the broadside or in some form of barbette.

Power of Guns required.—It results from this that all the unarmoured and protected ships, and all the second class ironclads, amounting to more than 50 per cent. of the whole, can have their artillery silenced by at least the lighter armour-piercing guns, and in many cases by any gun, even the smallest. The same is the case with many of the first class ships. There are no guns which are absolutely secure from injury from light projectiles. It is doubtful if there is a single ship which could unconcernedly endure serious injury to her unarmoured portions. It follows, therefore, that very heavy guns are required in coast batteries only in places which are liable to be attacked deliberately by first class ships. Elsewhere the smaller armour-piercing guns are sufficient. In all cases the greater part of the work can be done by them, and they should form the larger part of the armaments. Of these the most generally useful is the 6-inch B.L., being powerful, accurate, and easily handled. The old 9-inch and 10-inch R.M.L. guns are also valuable for their large shell power. It may, in some cases, be desirable to use the B.L. armour-piercing guns of medium power, namely, the 9·2-inch and 10-inch, more especially to penetrate thin armour at long ranges, and also to gain the advantage of their accuracy and shell-power. They also reduce the number of ships that would have any chance against the port where they were mounted. Small Q.F. guns will be very useful but cannot be expected to produce decisive results, as special attention is given to protecting ships' guns against them. Any and every gun available should be brought into action against a ship, but of course judgment should be exercised as to whether to fire at her guns, or at her unarmoured ends.

The probable increased use of thin armour in ships, for the special purpose of keeping out projectiles from Q.F. guns and common shell with high explosives, makes it undesirable to mount permanently on coast defences guns like the 64-pounder R.M.L., which are devoid of all armour-piercing power. The use of the 7-inch R.M.L. is, however, justifiable; though it is slow and not very accurate, it can be mounted in a way which gives great security to the detachment.

The introduction of high explosives has greatly increased the value of the old M.L. guns with their great shell power, the more so that by some modifications their range and accuracy can be greatly increased. By using them as howitzers, always to be fired at a high

angle, increased protection can be gained for the battery, combined with the advantage of attacking the ship in a very vulnerable part, namely the deck. These are useful additions to the defences of harbours of all degrees of importance.

Class of Defence required for any given Fortress.—This obviously depends, in the first place, on the class of attack to be expected, and this again is liable to vary under the influence of changing political and military considerations, so that it cannot be absolutely foreseen. It is possible, however, to judge within certain limits what is likely to happen, and against this provision should be made. In devising schemes of defence probabilities, not possibilities, should be considered, or the preparations would overweight us and we should be as weak as before, though from another cause.

The main defence of British possessions must always remain the Fleet. A serious attack on a fortress will not be made with first-class ships unless that portion of the fleet charged with its defence is withdrawn to a considerable distance, and unless the fortress is not far from the enemy's base of operations. These conditions might be fulfilled, for instance, in the case of Malta, as it is not altogether improbable that our Mediterranean fleet might have to be withdrawn. Malta, therefore, is an example of a fortress that should be armed with very heavy guns for use against first-class ships. The same conditions do not seem to apply to the home ports, as much of the attention of the navy must always be devoted to escorting commerce as it approaches our shores, and some portion of the fleet must therefore be at hand.

Abroad, second-class ironclads must be counted on as forming part of an enemy's cruising squadrons. Consequently, in the more important ports 9·2-inch or 10-inch B.L. guns must be mounted. Usually the former are sufficient. They will not be required in the minor ports as the certainty of injury from the smaller guns will render an enemy reluctant to use his ironclads in attack unless for an adequate cause, nor will they be wanted in places where the enemy cannot produce any results with long-range fire, but is compelled to come close in to the batteries.

In the smaller ports at home and abroad the 6-inch B.L. should be used, combined with the 9-inch and 10-inch R.M.L., for the sake of their shell power.

Rifled howitzers can be used in all places, but are more especially of value to command water in which ships might wish to anchor, or where they would be compelled to go at a low rate of speed. They are rather difficult to direct against vessels moving rapidly.

Q.F. guns should be provided for the purpose of firing over mine-fields against small vessels that might attempt to pass it or to injure the mines. They will also be very useful for firing against barbette guns' crews, and into ports; more especially when they can be placed on a height. The 3-pr. and 6-pr. Q.F. are most generally used for short ranges, and the 4·7-inch 45-pr. Q.F. gun for long ranges.

5.—THE NATURE OF THE ATTACK ON COAST BATTERIES.

In order that coast defences may be properly designed, it is equally necessary to know the manner in which they will be attacked, as, in the case of land forts, it is to know the ordinary methods of a siege, and how they are likely to be applied in the particular instance under consideration.

On Land.—The Engineers' Attack.—But there is a great difference between land and sea attacks, due to their being carried out by different services. In the case of land attacks, the Engineers are, so to speak, playing against themselves; they have to design both the works of defence and those of attack, and if after devising the most efficient mode of attack that they can contrive, they can build a fort that will hold out for a long time against it, they may rest pretty well satisfied with the solution of the problem of defence; at any rate, the question lies mainly in their hands. But in the case of coast works, they have only to deal with the defence.

At Sea.—The Navy Attack.—The attack is conducted by another service altogether—the navy—who will do it according to their own ideas of what best suits them.

It is useless, therefore, to theorise on this subject; we must discover what is the naval opinion on the best way of attacking land works, and provide against it. If we think that by operating in a different way they would find out a weak place in our armour, we should of course provide against it also, if possible, lest they should discover it too, but the point of the first consequence is that we should be strong against the style of attack that is likely to be made.

Naval Opinion on the Attack of Coast Works.—What then is the naval opinion as to the best way of attacking coast works?

The question, of course, can only be replied to by giving opinions collected from the various naval officers with whom the subject has been discussed, but I have hardly ever heard a different opinion than that they would get as close as possible and pour in as heavy and rapid a fire as they could. It is necessary, in order to obtain accuracy of fire, either to anchor, or to fire while rounding a buoy at a known range. This exposes the ship to attack by torpedo boats and rifled howitzers, but seems unavoidable.

From this may be seen the advisability of consulting the navy as to what they would do in the matter, instead of theorising as to what they ought to do; for it is a common opinion among military men that the ships ought to keep at a long range, and fire slowly and deliberately.

Personally, I thoroughly agree with the navy, being sure that their mode of attack is much more likely to terminate in their favour than the other.

Advantages of Attacking at Short Ranges.—A rapid fire of all sorts of missiles poured in at a short range would have a good chance of stopping the working of the guns, however mounted, and the fire once silenced, the ships would have it pretty much their own way.

They could then either land men and attempt to storm the works, or they could steadily pound the place with their heavy guns, at the same time setting to work to remove the obstructions.

Of course, it will be said that they run a greater risk of the loss of their ships; and no doubt this is the case, but then they stand a better chance of carrying out successfully the operation that they are engaged in.

A deliberate fire from a distance is not one which would silence the batteries, and as shot from heavy guns are effective when they strike at long ranges, the ships would still not be secure from injury, even if this mode of attack were adopted, while the operations would be much prolonged.

The only case in which long-range fire is likely to be used against forts, is when it is delivered from small gunboats armed with heavy guns, as part of a scheme of attack. This would then resemble the action of artillery in a battle on land, preparing for and supporting the close attack, but not superseding it.

The use of long-range fire in bombardment is another matter altogether, the mark being a large one, and shells doing as much injury to buildings and stores, whether they arrive with a high or low velocity.

Running past batteries arranged for the protection of a channel would of course be done at long range if possible; but in this case avoidance and not fighting is desired.

A deliberate attack on batteries would be a very serious affair for ships, and they would probably evade it, if possible, by landing troops to take them in rear.

EXAMPLES OF NAVAL ATTACKS.

Want of Modern Experience.—In the consideration of questions of naval war we labour under a greater disadvantage than in the case of operations on land, for we have very little modern experience to guide us.

The great continental wars of the last twenty years have supplied us with a large amount of information on the employment of modern weapons. Recently, the improvements in artillery, the introduction of high explosives in shells, and of the magazine rifle, and the increased use of machine guns, have made many points doubtful, but enough is left to be of great assistance in design.

But with naval warfare it is different. The accounts of the American Civil War were for some time almost the only ones to which we could refer for examples of the use of modern weapons of naval warfare against land works, and these were then in a very elementary stage. However, the ships, the guns, and the torpedoes were all fairly well proportioned one to another, and it is possible to argue from these experiences, due allowance being made for the quality of the troops employed, who appear to have been in many cases very unskilled in their duties.

Admiral Hamilton's paper on "Naval Operations during the Civil War in the United States," in the *Journal of the Royal United Service Institution*, Vol. XXII., 1878, gives a number of deductions from the operations in that war, which, although one may think them rather too favourable to the navy, and may consider that he does not lay enough stress on the small power of the guns used by the Confederates, are well worthy of careful consideration. See also *Battles and Leaders of the Civil War*, in four vols. large 8vo.

In the *Journal of the Royal United Service Institution*, Vol. XXV., 1881, is an account of the naval operations in the Chili-Peruvian War, by Lieut. Madan, R.N., which is also well worth reading.

The bombardment of Callao in that war, and the attempt to sink a corvette in the docks there by the fire of an 8-inch 12-ton B.L. gun, mounted in a merchant steamer, at a range of 8,000 yards, was the first use made in war of the new type of artillery. The fire was sufficiently accurate to make the Peruvians construct a large parapet of sandbags to protect the part of the corvette which rose above the dock wall, and this was occasionally struck.

The effect on the guns' crews of the explosion of a cartridge in the battery of the *Blanco Encalada*, was an illustration of what might very well happen again, not only on board ship, but also in a casemated battery on land. The men were terribly burnt, and the ship had to haul out of action at once to get things put right.

The fight between the Chilian ironclads and the *Huascar* was a practical experiment on the effect of projectiles on armour, for an account of which see Lord Brassey's *Naval Annual* for 1887.

In the *Professional Papers* of the Corps of Royal Engineers, Vol. IX., 1883, will be found an account of the attack on Lissa by the Italian fleet in 1866. The chief point of interest is the steaming of the *Affondatore* into the harbour, and her having to retire again after a 40 minutes fight with a battery which did not penetrate her armour at all, but which knocked her upper works about to such an extent that she was not fit to go into action against the Austrian fleet on the following day.

Bombardment of the Forts of Alexandria.—In 1882 we had the experience of the bombardment of the works at Alexandria, which somewhat modified several views, both of the attack and the defence.

Beginning with the attack, it is difficult to determine from this action what is considered the best method of carrying it out, for not only did different parts of the fleet act in different ways, but individual ships seem to have been allowed considerable independence of action, no doubt in part with a view to gain experience. It is said that it was thought unadvisable to expose the fleet to any risk of injury that could be avoided, in view of possible political complications which might result from the bombardment, and cause it to be required elsewhere. Hence the adoption of long-range fire. We can, however, discover from it various things which the ships find it desirable to do, and are thus enabled to consider the methods of preventing them.

The fleet was divided into three portions, the off-shore and in-shore squadrons, and the detached ships, the *Inflexible* and *Téméraire*.

The off-shore squadron began by moving in an elliptical course at the rate of about five knots an hour, firing into the batteries in rather a general manner, at ranges varying from 1,500 to 2,000 yards. After about 3½ hours of this, finding the batteries stronger than was anticipated, they anchored at ranges between 1,300 and 2,050 yards off Ras el Tin Fort, which was silenced in a couple of hours. Other batteries were fired at from the same position, but at longer ranges up to 3,100 yards, and finally the *Alexandra* stood in to 800 yards to dismount silenced guns.

The in-shore squadron opened fire at 1,100 yards from Fort Meks—one ship at anchor, two under weigh. The work was silenced in two hours, when two of the ships went in to ranges between 300 and 800 yards. Other batteries were shelled under weigh at ranges varying from 700 to 1,600 yards.

The *Inflexible* fought at ranges varying from 1,500 to 3,850 yards, and the *Téméraire* even fired a few shells at a range of 4,500 yards with good effect. These ships showed a tendency to close in during the day, but their long-range firing seemed quite as good as the rest. The *Inflexible* adopted the expedient of anchoring a buoy at a known range and steaming up to it to fire.

The accuracy of the fire was very fair, indeed better than one would have expected, but the results were less. It must be remembered that the action was fought against inferior troops in most indifferent batteries; badly designed, badly built, with their parapets often not high enough to cover the troops behind them from view. Nevertheless a considerable amount of fire was required to silence the guns, and it is evident that this was due to its not being sufficiently concentrated on them. When the ships really wished to dismount the guns they went into very short ranges. The machine gun fire did not produce much effect, but the ranges were too long for it except at Fort Meks. The impossibility in many cases of seeing the guns or embrasures added much to the difficulty of directing the fire.

We can hardly deduce from this action the range at which ships would engage forts under other circumstances than those which actually existed at Alexandria. It seems probable that knowing the quality of the force opposed to them, the English ships intentionally kept at such a distance that the enemy would be unable to deliver an effective fire against them, while their own superior gunnery would enable them to silence the artillery opposed to them. If this were so the reasoning was justified by the results, for the works were silenced, while the ships were comparatively uninjured.

The ships were benefited by the unusual calmness of the water, which assisted the accuracy of their fire. They were also favoured by the absence of submarine mines and of torpedo boats from the

defence. This enabled them to move about freely, and to anchor when they pleased without having to guard against any hidden danger. The Egyptians did not use their mortars against the anchored ships, or they might thus have forced them to move.

From the disposition and restricted arcs of fire of the Egyptian guns the ships were enabled to silence the batteries one by one, any work attacked being supported feebly or not at all by those adjacent to it.

With regard to the large amount of ammunition expended by the ships, that is partly to be accounted for by the long ranges used; and partly (and this applies more particularly to the smaller natures of ordnance and the machine guns) to the want of seriousness that there must have been about the whole affair, when the slight effect of the Egyptian fire became apparent. It cannot be believed that every shot of the smaller guns and of the machine guns was directed with the same care as was evidently bestowed, for instance, on the 80-ton guns of the *Inflexible*, or the 25-ton guns of the *Téméraire*.

There is nothing in this action to disturb the opinion that ships in attacking a properly built and manned fortress must fight at short ranges to obtain decisive results.

From the point of view of the defence it may be noted that several of the ships were forced to anchor in order to increase the accuracy of their fire. This may be prevented by the employment of torpedo boats, which would find opportunities of attacking under cover of the smoke; also by the use of rifled howitzers.

The howitzers should be mounted in such positions that they may not be exposed to be silenced, as the Egyptian mortars were, by projectiles directed at the heavy guns.

There is an interesting account of this action by Capt. Walford, R.A., in No. CXIX. of the *Journal of the United Service Institution* 1883, and an admirable report, illustrated by plans and photographs, has been written by Capt. G. S. Clarke, R.E.; the latter publication is, unfortunately, "strictly confidential," and therefore not easily accessible, but it should be read by any who can obtain the use of it.

Landing Parties.—A naval officer informed me in 1884 that a squadron of eight ships, forming a small force of say two ironclads and six unarmoured corvettes, which might very well be sent on a combined cruise, could land a force of 1,200 men, while still retaining enough hands on board to manage the ships under steam, and to work one broadside of the guns. 1,200 men is a fairly large body to dispose of, and might out-number the troops available at any one point to resist a landing. Since 1884 the style of construction of war ships has altered considerably, and a squadron of modern vessels would have hardly any men available for a landing party out of their fighting crews. A squadron, however, that had any intention of attacking a fortified harbour would most likely be accompanied by other ships, such as armed merchant steamers or tenders, with supplies of coal and reserve ammunition, which would also give the accommodation necessary for extra men. It would, therefore, be a mistake to assume even now that there would be no chance of an attack by land in any case. As to the number of ships that may have to be encountered, it may be noted that in 1878 the Russians assembled a squadron of 11 vessels in an American port in readiness to attack our commerce in case of a declaration of war.

6.—OBJECTS OF COAST BATTERIES.

Objects of Coast Batteries.—The various objects for the attainment of which coast batteries are built, are the following:—

1. To close the passage of a river or channel.
2. To protect a town or dockyard from bombardment.
3. To deny an enemy the use of an anchorage.
4. To defend a landing place.
5. To deter ships from attacking the flank of a line of works ending on the sea.

Treatment of the different cases briefly indicated.—These all require a certain difference of treatment, for which reason they are classed in this manner, and it may be briefly indicated in what this difference consists before going on to discuss them in detail.

1. *Closing a Channel.*—Ships may try to pass the fortifications of a river or channel in two ways, either by running past, in which case they would keep as far from the batteries as possible, or by silencing the guns or capturing the works, so that they may pass at their pleasure.

Requirements.—To stop running past, either the obstructions, such as booms or submarine mines, must be sufficient and in position when wanted; or the guns must be so numerous and powerful as to be reasonably certain of inflicting serious injuries on the ships; or they must be supplemented by locomotive torpedoes.

On the principle of having two strings to one's bow, it is advisable to combine these methods as far as possible, therefore a good line

should be chosen for submarine mines, powerful guns mounted which will be effective at the further side of the channel, and the works so arranged that their fire shall cover a large area of the water, either by placing them at bends in the channel, or by spreading them out along the shore. It is a particularly suitable case for the employment of locomotive torpedoes.

The precautions against close attack, such as strong parapets and solid traverses, are the same as for all coast works.

2. *Protection from Bombardment.*—To bombard a place the enemy must get within a certain distance, dependent on the range and accuracy of his guns.

To protect the place he must be kept outside a circle centered at the place to be defended, and with this distance as radius as a minimum.

If the works can be placed near the circumference of the circle, the problem becomes the same as the first one—the defence of a channel—as the enemy must pass the works to get within range.

If the works cannot be so placed, the only thing to be done is to mount straight-shooting guns, which will hit hard at long ranges, as far in advance of the place as possible, in order to try to drive off the enemy before he has done much injury.

It often happens that the batteries have to be built close in to the town or dockyard to be protected; in this case the problem is insoluble by military means, and the place can only be completely protected from bombardment by a naval force. Batteries, however, might be still of much use. They would support the ships and lessen the freedom of the enemy's movements, while if the defending vessels were absent they should prevent the enemy coming close in, and so bombarding with more accuracy and effect than at a long range.

Requirements.—Long-ranging guns mounted so as to cover a large area of water, and placed as far as possible from the point to be defended, are, therefore, the requirements in this case. Rifled howitzers would often be useful.

3. *Denying the use of an Anchorage.*—A single gun firing on an anchorage would be enough to deny the use of it to an enemy if it could not be silenced; no ship could stand the constant worry, even if she could not be materially injured. She would do all she could though to put a stop to the annoyance.

Requirements.—A work, therefore, intended to deny the use of an anchorage to an enemy need not mount many guns, nor need those mounted be of the heaviest description, but they must be very carefully arranged so that it shall be very difficult to silence them, and the work generally must be strong on all sides. Rifled howitzers are peculiarly well suited for this purpose, on account of the way in which they can be concealed.

4. *Defence of a Landing Place.*—In defending a landing place the actual landing would usually be resisted by medium or light guns, which would fire on the beach and the near waters, and which should be protected as far as possible from the fire of ships.

Requirements.—If these could be entirely concealed from view from the deep water nothing more would be required, but this may not be possible, and they may have to be defended by heavy guns from the attack of ships.

A few guns, well mounted, are usually enough for this.

As the enemy must come in close to do any harm, it will not be necessary to cover a large area, but the battery must be prepared to resist a determined attack at a short range.

5. *Defence of the Flank of a Line of Works.*—This case is similar to the former. If a line of land works ends on deep water free to the enemy's vessels, it is necessary to prevent his assisting a land attack by his ship guns.

Requirements.—Powerful guns must be mounted to keep him off as far as possible, and these must be protected in their turn from his land batteries. Many guns are not necessary, as the ships must be in action for some time to produce an effect on the works, and consequently each gun will have the opportunity of firing many rounds.

Here, again, concealed howitzers afford a solution of the problem, which without them it would seem only possible to meet by giving the guns overhead cover, *i.e.*, by using casemates or turrets.

Submarine Mines.—In all these latter cases submarine mines may be used as adjuncts to the artillery defence, at least wherever the local conditions admit of it; but they are not of such importance as when a channel has to be closed. They might be arranged so as to restrict the manœuvring of the attacking ships, and thus to give the guns of the defence a greater chance of hitting.

Navy to be consulted as to Sites of Batteries.—Before considering the principles which should govern the character and position of the batteries to be used, it must be noted that since, as we have seen, the navy choose the mode of attack, so they must always be consulted before selecting the positions for batteries to fulfil the objects mentioned above; for they alone can point out the places where ships

would engage with least advantage; where they would be hampered in their movements by the shape of the channel, by the set of the currents, or by the violence of the waves; and, on the other hand, they will be able to show where the circumstances are most favourable for the ships, where they might evade or run past the batteries, or fire at them under conditions which tell in their own favour.

Something of these reasons should, of course, be known to us, so that, as far as we can, we may guard ourselves from proposing to build works in situations where they would be unnecessary or ineffective. At the same time a naval opinion should always be obtained if possible before preparing designs.

Choice of places to fortify usually decided by the Navy.—Our own navy has usually a further influence on the works besides that just mentioned; for, practically, they, as a rule, decide what places we are to fortify. The choice of a harbour at which Her Majesty's ships shall coal and refit has usually to be made long before the question of fortifying it arises. Generally, indeed, it is resolved to fortify it because the interests bound up in the place have become so large that it is necessary to safeguard them.

Consequently, the engineer is, as a rule, called on to design works to protect a place which has been chosen entirely without reference to its capabilities for defence, and in which, very often, the docks and buildings have not been placed in the most advantageous positions for that purpose. It is very rarely indeed that a naval station is chosen because it can be easily fortified. As a result of this, the problems of defence are very varied, and seldom easy to solve satisfactorily.

Often impossible to secure a place from bombardment.—Indeed, it is constantly the case that it is impossible to prevent a place being bombarded at long range, owing to its being so close to the open sea.

Therefore attain some other definite result.—The only thing to be done, therefore, is clearly to determine what is wanted in any case, and to attain as much of it as possible, securing, however, some definite result.

Either deny the harbour to an enemy; or prevent him from bombarding from short ranges; or make sure of having one entrance open to your own ships, even if there are others which cannot be completely stopped, so that at the worst the place can be relieved; then the rest must be left to naval means.

It may very well happen that the difficulty of attaining a complete success may deter the enemy from attacking at all.

Harbour Defence Vessels.

Places should not depend for their defence on Naval means.—It may here be remarked that it is an easy way out of any difficulty in projecting the defences of a place to summon up mentally the British fleet to supply the deficiencies; or, at the least, to call up the vision of a coast-defence ironclad, or of some gunboats permanently stationed at the spot; but such dreams should not be yielded to, as they cannot be realised.

For what does the provision of a ship permanently told off to defend a particular place, and not to be removed thence, mean! It means that the admiral on the station, whose *raison d'être* and business it is to defend British commerce and British possessions there, of which the port in question is a part, is permanently deprived of a portion of his fleet, which, whatever the emergency, he is not to use away from a certain fixed point, whether that point be in immediate danger or not.

He may think that the best defence is to take the offensive, and one more ship might make the turning point in a comparison of strength between himself and the enemy, but there is this ship permanently detached, and able only to defend the one port in the one way; instead of adding to the protection of the whole station, this particular port among the rest. Of course any admiral would at once remove such a ship from its port if he had reason to believe he could employ it advantageously elsewhere.

In order that an admiral may not use his discretion in this way, it has actually been proposed to build ships that could not safely be removed from the places they were intended to defend. Deliberately to build bad ships is the *reductio ad absurdum* of this system.

On the other hand, because a squadron is entrusted with the defence of a particular portion of the British possessions, such, for instance, as the West India Islands, its presence must not be counted on before every port that may be attacked by the enemy; it might be thrown off the scent, or engaged elsewhere at the time it was wanted there; consequently, every fortified place must be prepared to defend itself to the best of its ability. It will be the business of the navy to relieve it as soon as possible.

A Place should be as complete as possible in itself.—The deduction from this is, that a place should be as complete in itself as possible, regard being had to the scale on which the defences are being carried out; there should be no gaps left to be filled up by floating batteries or harbour defence ironclads.

If there be a want—if, for instance, the place cannot be protected from bombardment—the admiral will know of it, and he must take his measures accordingly; but he is entitled to demand that the place should be able to hold out during his absence for a short time, dependent on the distance of the relieving force, against any attack which may be reasonably expected to be made; otherwise, it is not much good fortifying the place at all.

Local Floating Defences.—The necessity of being independent of naval assistance does not involve dispensing with local means. It is essential to have scouts to give warning of the approach of a hostile force, and very desirable to have armed vessels to protect traders approaching the port. These requirements can be met by arming tugs and merchant ships. Torpedo boats would be of great assistance in most places, and will often be provided; but even then they must not be counted upon as always certain to remain there.

7.—DISPOSITION OF COAST WORKS.

We may now proceed to consider in somewhat more detail the nature and position of the works that would be necessary to carry out the various objects before enumerated.

1. *Closing a Channel.*—To close a channel it is necessary to keep the enemy's ships a long time under fire, in order to ensure their being seriously injured and put out of action.

This end may be attained either by forcing them to slacken speed before the batteries, or by mounting a large number of guns.

Choice of a Position.—The former method is, of course, the best to adopt if possible, so a position should be chosen for the batteries where the channel is either obstructed or sharply bent, or where submarine mines can be laid.

These points are the first to look to in considering the defence of a channel, for it not unfrequently happens that the position that looks most suitable on the *map*, proves quite the reverse when the chart and the sailing directions are consulted; the water may be too deep for mines, or the current too swift, and then there is no choice but to try to find another position.

Arrangement of Batteries.—The manner in which the batteries are arranged when once the general position is selected, depends to a very great extent on the accidents of the ground, but they may either be massed near the obstruction, or spread out along the side of the channel. The latter method is preferable, as it gives a somewhat better chance if the obstruction be not in place when required.

However, this is usually decided by other considerations than pure tactics; such as the nature of the ground, the number of guns available, the money to be spent on the batteries, and the number and quality of the troops; it is cheaper to mount a certain number of guns in a few works than in many; it takes a less number of men, and they are easier kept in hand if they are not first-class troops. From this it may be inferred that it is only first-class fortresses that have their approaches defended by a long string of works. The defences of the Needles channel (Portsmouth, *Plate* I.) are an example.

Second Line desirable.—It is very desirable to have a second line of works in places of any importance. They tend to neutralize the effect of any failure to hold the front line and give another chance, and they also prevent the enemy passing the first line without reducing the forts, as he would otherwise find himself between two fires.

The second line should, if possible, be placed near enough to the front one to come into action with direct fire immediately the latter is passed; otherwise the enemy's ships will have a space in which to reorganize themselves before proceeding to another attack; also the second line will assist in covering the obstructions, and will bring long-range fire to bear in front of the first line.

The position of the second line should be chosen on the same principles as the first line, and may also be provided with submarine mines.

Small Fortresses.—In small harbours the place of the second line may be taken by a citadel or some interior work, whose guns command the harbour.

In very small places there may be no question of second lines, or even of interior works.

There may be half-a-dozen or less guns allotted which have to be made the best of, and to be disposed so as to ward off as many forms of attack as possible.

In this case the principle still holds good as to how a channel should be closed; as heavy a fire as possible should be brought to

bear on the water just in front of the line of obstruction. A line of submarine mines and two or three disappearing guns might cause considerable delay in forcing an entrance, which in many cases would be equivalent to securing the place.

2. *Protection from Bombardment.—Portsmouth, Plate* I.—The works that close the passage of a channel sometimes also serve to keep the enemy at such a distance that he cannot bombard the place to which it leads. If the channel be blocked at such a distance off that the enemy must pass the works in order to get within range of the town, the further end is thus attained.

But it is often the case that it is not so. The distance at which a town can be bombarded may be taken at 10,000 yards, or about six miles. The shooting from ships at that range would undoubtedly be rather wild, but a town is a big thing to hit, and the projectiles would arrive with quite sufficient velocity to smash up ordinary buildings. The present long guns, too, are much more accurate than the old short ones.

Now six miles is a long way out to push one's works, and moreover, there are not many harbours which have approaches of such length. (Portsmouth, *Plate* I.; Malta, *Plate* II.) Consequently the batteries closing the channels of approach have usually also to ward off a bombardment as far as it is possible for them to do so.

If they have this double *rôle* to fill, it would in many cases be advisable to retire some of the batteries, so that the first brunt of the action may not fall on them, but that they may be reserved against a serious attack. They should, however, be able to help with their long-range fire in the earlier stages of the affair.

Bombardment cannot do much harm.—The mere bombardment of a place is a very partial triumph; it must be uncertain in its action, and, except on the civil population, can have little effect; against dockyards and naval stores the results would be very small, as they contain so little nowadays that can be injured in that way, with the exception of machinery.

Stores of iron cannot be hurt much; coal will not catch fire from shells fired into it; docks and wharf walls require most deliberate operations to injure them seriously; they must be blown up, not chipped about with bits of shells; so that it would hardly pay to bombard any place but a commercial town which might be frightened into paying a ransom. The things in a dockyard that can be seriously injured by distant shell fire are machinery, dock gates, and ships undergoing repair. Machinery might in some cases be protected by bombproof cover. There is no reason, except the cost, why this bombproof cover should not be built in peace time, as well as the forts, but as a matter of fact it will in all cases have to be improvised when likely to be required.

Nature and disposition of Guns to prevent a Bombardment.—Guns mounted for the purpose of keeping an enemy's ships at a distance need not be very numerous, for the operations of a bombardment must be somewhat lengthy, and there will be plenty of opportunities of getting hits; but they must be securely mounted, so that the enemy shall not be able to make a gap for himself by silencing a few of them, and they must cover with their fire the whole area of water from which the enemy can attack, and it may be noted that he can of course bombard over an intervening strip of land.

The best style of battery for keeping ships at a distance is one for barbette guns, if tolerably high ground can be got for a site, or if not, for disappearing guns. The help that the guns give one another, owing to the large arc of fire that it is possible to give them with these mountings, enables their numbers to be reduced to a minimum without incurring the danger of leaving blank spaces through the silencing of one gun. To close a channel on the other hand, it used to be considered necessary to casemate at least some of the guns for their greater security, for the enemy is likely to attack the batteries built for this purpose with greater determination than any which are merely meant to keep him at a distance, the results to be attained by him, if successful, being so much greater. The modern way of meeting the difficulty is to have works dispersed so as to bring a fire to bear from various directions; disappearing mountings, concealed howitzer batteries, and locomotive torpedoes being used.

3. *Denying the use of an Anchorage.*—The denial of a harbour to an enemy is the minimum to which its defence can be reduced. It merely means that it can be of no use to oneself, and therefore shall be of none to him; it is all that remains possible if one is worsted in a defence of the approaches, and in many cases it is all that requires to be done, for instance, when the defence of one harbour renders it necessary to take steps to prevent the enemy using any adjacent one which he might make a base of operations. For an example, see Marsa Scirocco in Malta, *Plate* II.

In the defence of first-class ports, such as Portsmouth, it is not worth while to make any arrangements for firing on the harbour; it is essential that the enemy should be kept outside, and that your own operations within should be unimpeded; but in the case of

small harbours and coaling stations, it is a good precaution to have a few well protected guns or howitzers bearing on the inner waters, thus enabling the garrison to keep up the fight to the very last.

The work in which they are mounted will become the citadel of the sea defences, and might also be that of the land defences as well, so as to have the greatest possible concentration and to enable the smallest remains of the garrison to hold out.

Time gained is everything in fortification, and a few hours resistance may enable a relieving fleet to arrive. The defence of Lissa in 1866 is an example of this.

Small Harbours.—In small places, where there are few guns available, it is necessary to get as much work out of them as possible, and those intended to command the inner waters will usually also have to be arranged to fire on the entrance. It is of great importance to get as many guns as possible into action at an early stage of the attack when the ships are at a distance, and when their fire is, therefore, more inaccurate than that of the land batteries, which have the advantages of range and position-finders.

In the defence of a roadstead it is of great importance to cover all the waters with fire, as in such a place it is usually difficult to arrange obstructions, and an enemy's ship might otherwise be able to run in and take some of the batteries in reverse.

Harbours which are not required by the Defence.—In the case of harbours which it is desirable to prevent the enemy from using, but not necessary to preserve as a refuge for the ships of the defence, it is often sufficient to be able to fire on the inner waters only, and not on the approaches, and the guns may therefore be so mounted as to be unattackable from the exterior, as was the case at Fort Delimara, Malta; this forces the enemy to come into the narrow waters of the harbour before he can attempt to silence them, thus making him fight at a disadvantage. It also lessens the number of guns required.

A work in which guns are thus mounted will require protection from the fire of ships taking them in reverse, but this may be obtained by massive construction without its being necessary to provide heavy artillery on the seaward faces.

The guns used need not be of the heaviest class, as rapidity in producing an effect is not so much of an object as it is, for instance, in the defence of a channel. While the guns are firing, the enemy cannot land men or get on board stores; but they must be very safely mounted, so as not to succumb to a protracted assault.

Exposure to a Land Attack.—If a work is at all isolated, as those of this class often are, careful precautions must be taken against a land attack, which might be attempted as a preferable course to risking ships against it. This condition used to render it necessary to casemate at least some of the guns, in order to shelter them from curved fire. The case would now usually be met by mounting concealed rifled howitzers and some disappearing guns, not of great weight, but rapidly worked and giving a small mark.

As a land attack has to be provided against as well as one from the sea, and as the armour-piercing power of the guns is not of such great consequence, the formation of the ground has a great influence over the choice of a site for works of this nature; they should be placed where the natural advantages give them the greatest strength, even if a loss of range for the heavy guns be the result.

4. *Defence of a Landing Place.—Portsmouth* (*Plate* I.).—*Sandown Bay, Isle of Wight.*—The defence of a landing place does not necessarily require any heavy guns at all; indeed, when they are used they are the defence of the defences rather than the actual defences themselves.

For the landing may be best prevented by the fire of light guns along the shore, destroying the boats and men as they approach, or while the disembarkation is going on; if these guns can be so arranged that they cannot be injured or silenced from seaward, an ironclad can do nothing to help the landing, and there is, therefore, no object in providing guns to fire at one. If, however, it is impossible to get security for the small guns by concealing them, it must be attained by mounting guns which will drive off the covering ships.

The fire of these guns need only sweep the water from which the flanking batteries can be attacked. Their number need not be large, but the protection given to them should be good, for the operation of effecting a landing in the face of permanent defences is a hazardous one, and must be carried out with energy if it is to succeed; the works, therefore, will be attacked vigorously, if they are attacked at all.

The guns must be of sufficient power to beat off the attacking ships before they have inflicted much damage on the flanking batteries of lighter guns; if these guns are very well protected so that a long bombardment will be necessary to silence them, the covering battery will have plenty of time to act, and its guns need not be so powerful as if they were obliged to produce an effect

promptly, for an ironclad could not stand a continuous pounding even from guns which could not pierce her in single shots.

5. *Defence of the Flank of a Line of Works.—Malta* (*Plate* II.), *Fort Maddalena.*—The case of a battery which is intended to protect the flank of a line of land works is similar to the last, and only differs from it in two points, viz., it is not necessarily liable to be attacked by troops landed for the purpose, and it is almost necessarily exposed to an attack from siege works such as are directed against land forts.

In view, therefore, of the accuracy which is attainable by the fire from them, it is necessary to take particular precautions against danger from this quarter. It used to be necessary to provide the guns with casemated cover. It is now sought to attain the desired end by using concealed howitzer batteries and disappearing gun mountings. Barbette batteries near the land works cannot be counted on to remain efficient during a siege, as no amount of height in the traverses will make the guns safe against curved fire.

It is desirable to place a battery for this purpose somewhat in rear of the fort it is intended to support. It is thus safe against a land attack while the fort holds out, and the fire of any ship attacking is divided between the fort and the battery.

8.—POSITIONS FOR COAST BATTERIES.

A High Retired Battery the best, not always possible to adopt.—In deciding on the best position for coast batteries, as in other similar points in connection with coast defences, it is first of all necessary to ascertain what is the opinion of the navy on the subject. They would probably reply to such a question that the battery that ships would least like to engage would be one high up and somewhat set back from the deep water. A battery so placed could direct its fire against the decks of the ships, which is the most vulnerable point about modern ironclads, and the efficiency of this fire would increase as they came in, and also they would not be able to get close enough to silence the guns by a heavy fire of small projectiles. Such a site is also a convenient one for the engineer; he has none of the difficulties of foundations and of sea walls, of a restricted area to build on, and of insufficient protection to his magazines except at great cost, which he meets with when building down at the water's edge, but he has usually plenty of space at his disposal. He also has a wide field of view for his guns, and can take advantage of it by mounting them *en barbette*. Nevertheless, there are plenty of batteries not placed in this manner, and that for a variety of reasons, of which the principal is that it is not always easy to find the necessary configuration of the ground. The position and nature of the channels of approach usually dictate the sites of the batteries; it is often necessary to push the guns forward either in order to get the fullest effect from their penetrative power, or to get the longest possible ranges from them, and this condition often necessitates placing the batteries on the low ground close to the water. In such a situation it used to be considered necessary to casemate the guns; at the present time they would be mounted on disappearing carriages, unless, indeed, shoals or rocks stretched out so far in front of the battery that ships could not approach within a mile or so of it, in which case the guns might be *en barbette*.

The height of a battery above the sea tells in two ways: by adding to the security of the gun detachment, and by increasing the efficiency of the fire through its being rendered more plunging. The first cause is of the most effect at short ranges, where the trajectories are naturally flat, and where, consequently, a slight addition to the angle of elevation is enough to prevent the projectile having a descending angle as it comes over the crest of the parapet. Thus the 9·2-inch B.L. gun, firing at a range of 2,000 yards at a battery 100 feet above it, will only get a falling trajectory for its projectile of 0° 41′. The drop of the shot due to that range is only 1° 38′, and the height of the battery subtends an angle of 0° 57′.

As the ranges increase, the elevation due to height bears a much smaller proportion to the drop due to increased distance. At a long range, however, it will be a pure matter of chance if a shell just shaves the crest of a parapet so as to be dangerous to the detachment behind it. It is only at short distances that the fire of a ship can be directed with sufficient precision to have any approach to certainty of striking the small area which is vulnerable in a barbette battery of the present day.

The other advantage of height, namely, the increased effect of the plunging fire is one which cannot be often attained in any great degree. It may be taken that a really effective fire of this class is obtained when the projectiles drop at a minimum angle of 10° with the horizon, this being the angle at which the strength of the protective decks is calculated as equal to the side plating. Now the following table, showing the angles of incidence at various ranges

of the projectile from a 64-pounder, mounted at different heights above the sea, brings out the fact that to get this result at all ranges the gun must be mounted at a height of between 500 and 600 feet above the water.

A height of 100 feet produces but little effect, even at the short range of 500 yards.

The armoured decks which are in common use even in ships otherwise without armoured protection, are therefore likely to prove very effective defences in the case of a naval attack on land batteries. They do not, however, secure the guns from injury, but only the flotation and engines.

With regard to heavier guns than the 64-pounder, they will require to be mounted at greater heights to get equal angles of incidence from the shot. The old R.M.L. guns will not have to go very much higher, but the new B.L. guns will, as their trajectories are so much flatter.

Table showing the Angles of Descent of the Projectiles from the 64-pounder M.L.R. Gun of 64cwt., mounted at various heights above the sea level. 12lbs. Charge; 90lbs. Projectile.

Height of Gun in Feet.	Range in Yards.	Angle of Line of Sight.		Angle of Incidence due to Range.		Actual Angle of Descent of Shot.	
		°	′	°	′	°	′
100	500	3	49	0	55	4	44
	1,000	1	55	1	52	3	47
	1,500	1	17	3	7	4	24
	2,000	0	57	4	42	5	39
	2,500	0	46	6	36	7	22
	3,000	0	38	8	57	9	35
200	500	7	38	0	55	8	33
	1,000	3	49	1	52	5	41
	1,500	2	31	3	7	5	38
	2,000	1	55	4	42	6	37
	2,500	1	32	6	36	8	8
	3,000	1	16	8	57	10	13
300	1,000	5	43	1	52	7	35
	1,500	3	49	3	7	6	56
	2,000	2	52	4	42	7	34
	2,500	2	18	6	36	8	54
	3,000	1	55	8	57	10	52
400	1,000	7	38	1	52	9	30
	1,500	5	5	3	7	8	12
	2,000	3	49	4	42	8	31
	2,500	3	3	6	36	8	39
	3,000	2	31	8	57	11	28

Table continued.

Height of Gun in Feet.	Range in Feet.	Angle of Line of Sight.		Angle of Incidence due to Range.		Actual Angle of Descent of Shot.	
		°	′	°	′	°	′
500	1,000	9	29	1	52	11	21
	1,500	6	24	3	7	9	31
	2,000	4	48	4	42	9	30
	2,500	3	49	6	36	10	25
	3,000	3	13	8	57	12	10
600	1,000	11	19	1	52	13	11
	1,500	7	38	3	7	10	45
	2,000	5	43	4	42	10	25
	2,500	4	35	6	36	11	11
	3,000	3	50	8	57	12	47

Batteries used to be constructed near the water level to get the advantage of ricochet fire, but it need hardly be said that this is absolutely out of date. A miscalculation of range is of less account when firing from a high battery than from a low one, as the target is greater since it includes the deck as well as the sides of a ship. On the other hand when ranges are accurately known, as is the case when a range or position-finder is in use, a smaller defect in the shooting of the gun will cause a miss. Therefore, if there is any choice in the matter, a battery should not be placed on the very highest ground available, but this should be reserved for the position-finder, whose efficiency will be increased thereby, as will be explained in the next chapter.

Sometimes a battery placed on a bluff cannot see the water immediately underneath. This may give an opportunity for small vessels to slip in, and perhaps to do some mischief, and is a point that should always be attended to. It may be necessary to mount some guns to see this water, or to block up the channel partially.

It may here be observed, for it is often forgotten, that the curve of the trajectory of the shot from a high battery must be taken into account in determining the area of the water commanded by it; it sometimes makes a great difference in the amount commanded by the guns.

Height for a Battery.—The old rule used to be that a barbette battery should not be less than 100 feet above the sea, and it still seems to be a good one to follow. 1,000 yards is about the limit of possible good shooting for machine guns from ships. With batteries

100 feet above the sea, the trajectory at that range would be nearly horizontal (2° depression from the 1-inch Nordenfelt), so that a properly-made parapet would protect the battery from such projectiles. It would not protect it from shrapnel shells, but until these can be burst with accuracy they need not be much feared.

High Level Batteries for Light Guns.—Seeing the dislike of ships to engage a high level battery, it is a natural deduction that a high level battery of some sort should in all cases be provided if it be possible, even though all the heavy guns be mounted near the water level. For even a battery of field pieces may effect something against a ship which is built, as a rule, to resist fire from the guns of other ships nearly on a level with herself, and which has many openings through the decks, such as hatchways, funnels, etc., which can only be partially closed, and masts, at least for signalling, which, if shot away, may hamper her movements. Therefore, one of the preparations for the defence of a coast fortress should be the throwing up of batteries on any high ground near the shore for whatever guns may be available. These batteries, if containing good guns, will also be useful against gunboats firing from long ranges.

Rifled howitzers give a means of attacking ships' decks, which is independent of the height of the battery above water. If there is a choice in the matter it is, however, desirable to place these weapons also on high ground, both because they are then more easily screened from view, and also because it enables them to be directed, if necessary, by depression range-finder from some point adjacent to the battery.

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Chapter 5

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are mounted on what are called small-port carriages, which, by allowing the gun to be raised bodily to different heights to suit the elevation or depression required, enable the size of the port to be much reduced. The system is, in fact, one of partial muzzle pivoting.

7-inch R.M.L.—The 7-inch 6½-ton R.M.L. guns in the land service are mounted on "6 feet parapet platforms," similar to those of the 64-pounder described in Chapter I., Section 1, and they will go in the same emplacement. This mounting gives security to the detachment against all projectiles not falling at a high angle. A similar mounting is being experimented with for the 7-inch 7-ton R.M.L. gun.

9-inch R.M.L.—The 9-inch Mark VI. guns, which are the old 9-inch R.M.L. re-rifled, are either mounted on their old slides slightly modified, or are used as howitzers firing at angles from 30° to 70° on mountings of a special character.

2.—BARBETTES FOR R.M.L. GUNS.

Emplacements to take Dwarf Slides.—Muzzle-loading guns on dwarf slides, if on C or D pivot racers, are mounted in a sort of pit over the edge of which they fire; if on A pivot racers they are mounted in an emplacement similar in plan to a casemate, and fire through a shallow embrasure, the sole of which is 4 feet 3 inches above the racer.

The general dimensions of the latter emplacement are determined in the same way as for a casemate, a clearance of 4 feet from the extreme line of fire on each side being sufficient to give room for the slide.

The dimensions of the C and D pivot emplacements, which are called barbette emplacements, depend on the method of loading the gun, in the manner which will now be explained.

Older Forms.—The older forms of barbette for heavy guns were copied from those for the S.B. guns which were formerly in use, the height of the parapet above the racer being the same and being still retained.

The maximum radius possible for the emplacement was fixed by the necessity for the muzzle of the gun projecting at least a foot over the parapet when run out to fire; the minimum by the necessity of getting easily at the muzzle to load when the gun is run back.

Of course the smaller the emplacement the less chance there is of its getting hit, and the cheaper it is to build; consequently with the

old S.B. guns and with the medium rifled guns which replaced them, the parapet is brought in close to the front of the platform. But as the guns increased in size the height of the axis of the bore above the floor of the emplacement also increased, till it became too great for convenient working, and difficulties began to arise in connection with getting the shot to the muzzle.

Emplacement with Fixed Loading Stage.—To meet this the emplacement was increased in size, and a fixed step or loading stage, as it is called, was carried round the front of it. This step should be 7 inches high for 10-inch and 11-inch R.M.L. guns. None is required for the smaller guns, 7-inch and 9-inch.

This enables the numbers loading to stand high enough to enter the charge and ram home, and also allows the projectile when placed on it to be raised vertically to the muzzle without striking the parapet.

A great many emplacements for guns under 35 tons weight still remain in this stage, but further improvements were soon seen to be desirable on account of the great exposure of the gun detachment, the men being always visible over the parapet whether actually employed in working the gun or not.

Emplacement with Sunken Loading Way and Movable Loading Stage.—The following arrangement was adopted:—A trench called a sunken loading way was cut round the front of the emplacement, where the old step had been, to a depth of 7 feet below the crest, so that the men in it were well protected. In this trench a wooden stage was arranged to run on rails, of such a height that the men standing on it could reach the muzzle of the gun to enter the charge and rammer head. The ground behind the gun was lowered, so that it remained standing on a sort of drum of irregular shape, approached in rear by a ramp, or what is better, by two or three steps. There are many emplacements of this pattern. The men when not actually working the gun are in security; so they are when bringing up ammunition, when raising the projectile to the muzzle by means of the tackle affixed to the muzzle derrick, and when ramming home the charge by hauling at the rammer bell-ropes; but the numbers who stand on the loading stage to sponge and enter the charge are much exposed. Also, the gear in the slide being the same as before, the men while traversing, elevating, serving the vent and pointing the gun, have to stand on the drum or on the slide, and, as formerly, are only partly protected.

Present form of Barbette Emplacement for R.M.L. Guns.—A further improvement has been made to barbette emplacements which has increased the security of the larger part of the detachment. The drum carrying the racers is made circular, and the traversing gear is altered so as to work from the level 7 feet below the crest instead of 4 feet 3 inches. A convenient crane for raising the projectiles is supplied instead of the old muzzle derrick fixed on the gun, and a stage fixed to the slide is used to load from, instead of a movable one running on rails.

The result of these alterations is that the only numbers exposed are those entering the charge and the rammer, those at the elevating gear who are partly protected by the gun, and the No. 1 who lays, who also gets a good deal of protection in the same way. This is not perfect, but it is much better than it was. It will be understood that the alteration to the traversing gear cannot be applied to a D pivot slide. With an A pivot the sunken loading way cannot be carried round to the front, and so the loading numbers must be exposed.

In all new emplacements for 10-inch and 11-inch R.M.L. guns, therefore, the drums should be made circular, with a radius of 8 feet 3 inches, the top, to a depth of 6 inches, being formed to a radius of 8 feet 1 inch, to give clearance to part of the traversing gear.

The drums for 9-inch guns must at present be made to a radius of 6 feet 3 inches in front and 8 feet in rear, the additional material being intended to give better support to the racer. This expansion is objectionable, as it interferes with the movements of the stage fixed to the platform, and prevents the gun having a larger angle of training than 180°. An improved method of fixing the racers and pivot, by which they will all be combined together by an iron frame-work with radial arms, will, however, enable the expansion to be done away with.

Foot-holes should be formed at intervals round the drum, at a height of 1 foot 3 inches from the ground.

The drums in all new barbette emplacements for R.M.L. guns should be made in this form; if the traversing gear is not modernized the necessary extension of the drum in rear can be made either in inferior concrete or in earth retained with planking so as to be capable of easy removal. Existing emplacements can be altered when required by cutting off the extension in rear, so as to form the drum into the required shape.

Mounting for "Long Range" Fire.—Certain improvements in the

rifling and projectiles for the 9-inch R.M.L. gun have made it capable, when altered, of accurate fire up to a range of 10,000 yards. To attain this range it must be capable of elevation to an angle of 35°, and various modifications of the mountings have been made to allow of this, and also to enable it to withstand the violent shock of recoil. Among other things, two legs are attached to the slide near the centre, which bear on a steel plate laid on the drum. This plate has to be set with extreme accuracy, which is very difficult to do while it is unconnected with the pivot and racer. It is now proposed to attach to the pivot casting eight radial cast-iron arms, on the ends of which will rest the racer, and upon which, near the pivot, will also be fixed the steel sweep-plates. This will be bedded in concrete, and will then practically form one mass, and will be comparatively easy to set.

The pivot will be 4 feet 7 inches long, and will have its top 1 foot $10\frac{3}{4}$ inches above the upper surface of the steel sweep-plate, which is 1 inch thick. The ends of the arms which take the racer are 1 feet 1 inch below the top of the pivot, the racer itself, which is coned, being about $2\frac{1}{2}$ inches high. In converting an old emplacement new racers and pivot will be required, and also new coned trucks to the mounting. (This has failed at 35°, but may do at 20°).

It is probable that in time this improvement will be introduced for the larger R.M.L. guns as they are altered for long range fire.

Dimensions for a Barbette Emplacement.—The dimensions necessary for the emplacement of any particular gun may be arrived at in the following manner.

Having obtained a drawing of the gun, carriage, and slide, start on paper a section of the emplacement, beginning with the pivot and racers. On this section mark the position of the muzzle of the gun when run out and when at extreme recoil. The latter point depends on the nature and position of the hydraulic buffers or compressors used, but the amount of the recoil is usually 6 feet.

These two points being found, the sunken loading way, 3 feet 9 inches wide, must fall between them, being limited on one side by the parapet, and on the other by the face of the drum carrying the racers.

The crest of the parapet should be kept in as far as possible, both to diminish the size of the emplacement and to get the muzzle of the gun to overlap it as much as possible, so as to diminish the unpleasant effects of the blast. It will be seen, though, that with a 6 foot recoil, and a sunken way 3 feet 9 inches wide, this overlap can be only 2 feet 3 inches at the most and may often be less, as at least one foot of the drum should be left in front of the racer for the sake of strength. The drum should be circular in plan, as described above.

If, as in the case of a long gun, such as the 38-ton, there is plenty of space before the racer, the front of the drum can be conveniently formed into one or two steps, but with a short gun, such as the 7-inch or 9-inch R.M.L., this cannot be done, and the drum must be cut down vertically. It may, though, have footholds cut in it.

The parapet follows the form of the drum, leaving a space for the loading way as far as the extreme lines of direct fire. It should then be spread out and sloped away, so as to avoid presenting a surface to catch projectiles that may just clear the front crest.

Barbette Details for R.M.L. Guns.

The following is a description of a barbette emplacement, such as has been recently constructed. For a drawing of a barbette emplacement for a heavy R.M.L. gun, see *Plate* XXXII.

Actual Pivot.—To begin with the centre, the actual pivot, which is always used in C and D pivot emplacements, is usually an old gun —a 24 or 32-pounder S.B., solidly set in concrete. If a gun cannot be procured, a cast iron pivot block, made for the purpose, can be used. The artillery supply, together with the carriage, a steel plug which passes through a hole in a plate fixed under the slide, into the bore of this gun. It is made to fit the 24 or 32-pounder used.

Racers.—Around the pivot is the racer or racers. These are set on granite blocks, or on iron chairs, as will be hereafter described, their position being determined by the pivot.

It is most probable that in future the racers in C pivot emplacements will be united to the pivot by being set on the extremities of a framework of cast iron bars radiating from the latter.

Training Arcs.—Radius of arc for 12·5-inch gun, 6 feet 9 inches; for 12-inch, 11-inch, 10-inch, 7 feet 9 inches; for 9-inch, 5 feet 10 inches. All for both C and D pivots. (See p. 240).

The Drum.—The drum on which the racers stand is best made entirely of concrete without any brick or stone edgings. By having the whole in one mass much greater solidity is attained, and the liability to displacement under the strain of firing is reduced to a minimum.

Foundation.—The depth of the foundation for the drum will depend on local circumstances, but it should never be less than 5 feet thick, or it may get cracked away from the pivot, and should always go down to solid ground. It is worth while with a big gun to take pains that no disturbance of the surrounding parapet or soil shall affect it so as to injure its rapidity or accuracy of fire, and this can only be attained with certainty by carrying the foundations of the racers and pivot down to some point which shall be quite out of the reach of the effect of the enemy's projectiles. It is worth while going down 30 feet to get a solid base; indeed, it is questionable whether it is advisable to mount heavy guns at all in positions where their foundations cannot be made quite secure.

Of course, while the material of the drum should always be the best Portland cement concrete, that of the foundation may sometimes be of inferior quality.

Sunken Loading Way.—Outside the drum comes the sunken loading way, which contains the loading stage rails, not required in new constructions. These rails are about $1\frac{3}{4}$ inches wide and $3\frac{1}{4}$ inches deep, and the gauge is 2 feet 10 inches. They are bedded in concrete so as to project $\frac{3}{4}$ of an inch above it, and care must be taken that this height is kept clear, or the movable loading stage will be thrown off the rails by its flanges striking the concrete. The stage will not go round a sharper curve than one with a radius of about 8 feet 6 inches to the centre between the rails. The rails must be kept $4\frac{1}{2}$ inches from the face of the parapet, or the stage will foul the parapet in going round. The rails may be procured, bent to the proper curve, through the War Office; any rail, however, of nearly the same section may be used.

The movable loading stage and its rails are not required when the mountings are fitted with the attached loading stage and crane, but these may not always be supplied in reconstructions when the movable stages may be in existence, so this description has been given. The dimensions of the loading way are the same in both cases.

Parapet.—The inner part of the parapet should be of concrete 8 to 12 feet thick, so as to give thorough protection to the drum, and to give a good surface for the gun to fire over. This upper surface must be well finished or the gun will find it out, for while even the blast of the 100-ton gun has no effect on good concrete, yet a much smaller gun will break up inferior stuff. No rendering or patching will stand more than a few rounds.

Recesses and Shelves required with Movable Loading Stages.—The inner face of the parapet was usually provided with recesses to enable men to get out of the way of the loading stage, and with shelves for projectiles. The recesses are 5 feet 6 inches high, 3 feet 6 inches wide, and 18 inches deep.

The shelves for projectiles were also recessed in the parapet, and were made of dimensions to suit the gun. Those for a 10-inch gun are 2 feet 9½ inches long, and 10 inches deep. The projectile rests on an oak or other hard wood slab, and the surface of this slab is arranged to be level with the top of the loading stage.

The object of these shelves was to enable projectiles to be kept ready for use close to the gun, in a convenient position for loading.

Recesses as now required.—In emplacements for guns with the loading stage attached to the slide, a continuous recess should be provided round the front at the level of the loading way in which to place projectiles ready for use. This may be 3 feet 6 inches high, and 12 inches deep, to take all natures up to 12·5-inch. The recesses for smaller guns can be of dimensions more nearly fitting their projectiles; but it will be probably found most convenient to adhere to one size. The projectiles are lifted from the loading stage level to the muzzle of the gun in one hoist.

Ring-bolts.—Round the emplacement three or four strong ring-bolts are fixed, for convenience in mounting the gun. They are usually placed about 2 feet below the crest. They should be countersunk, so as to be out of the way.

Eye-bolts.—At a height of one foot above the floor of the sunken way used to be several small eye-bolts, to take the snatch-block of the tackle which is attached to the muzzle derrick for raising the shell to the muzzle. They were made of ⅞ inch round iron, with an eye 1½ inch in diameter, and were fixed in the man recesses when there were any. These will not be required when the mountings are fitted with a crane.

Foundations of Parapet.—The foundations of the concrete portion of the parapet should be carried deep down; both to avoid displacement, and in order to protect the drum from the effect of the enemy's shells.

The concrete of the parapet should stop either at solid ground sufficiently firm to cause a shell to turn upwards, or should be continued downward till there is a sufficient mass of parapet in front of it to secure it from being undermined, so to speak. With modern sloping parapets this condition will be fulfilled if the ordinary requirements in the way of foundations are met. The quality of the

concrete may be reduced as it descends; the thickness must be uniform, or increasing, for constructional reasons.

Derrick or Davit; required only with the Movable Loading Stage.—The only fitting of a barbette emplacement that remains for notice is the derrick or davit used to raise projectiles from the ground to the movable loading stage. This is fixed at any convenient corner in rear of the emplacement, and the loading stage rails are brought up to it.

The derrick, as it is erroneously called, which is in use in many places, but which should not be repeated, is a small jib crane made of 2-inch bar iron. It is 4 feet high, and has a radius of 2 feet 7¼ inches to the centre of the eye at the end. It is supported at top and bottom by bars built into the side of the merlon.

The davit is similar to an ordinary ship's davit; it is made of 3½-inch bar iron, tapered to 2 inches at the end where there is an eye and ring. It is 8 feet 6 inches high, and its lower end rests in a shoe let into the floor of the emplacement. It is further supported at about 4 feet from the ground by an iron bar built into the wall of the merlon. It has a radius of 3 feet, and will lift 8 cwt.

The centre of the eye at the end of the derrick must be at least 3 feet 9 inches above the loading stage, or 7 feet 3 inches above the ground, to enable the projectile to be put on the stage.

Tackle with a double and a treble block is used to lift heavy shell by the davit or derrick.

Number of the Gun.—On the side of the merlon, close to the gun, should be painted up its number and nature, thus— $\frac{\text{No. VI.}}{\text{10-in., 18-ton R.M.L.}}$

Numbering from the Right.—The numbering is irrespective of calibre, and commences on the right of the battery, or part of the work in which the guns are mounted. (See *Regulations for the R.E. Department* on "Lettering Emplacements").

Mode of Loading.

Mode of Loading.—The following is a short description of the mode of loading, when the emplacement is provided with a movable loading stage.

The projectile is brought up from the shell store in a truck, and hoisted on to the movable loading stage by the davit. The stage is then run round under the muzzle of the gun; two men get on it and sponge out. The cartridge, which has been brought up from the store in its zinc cylinder, and extracted from it in the sunken way, is then handed up to them, and they put it into the gun. The projectile is then hoisted to the muzzle by means of tackle hooked to the muzzle derrick, and worked by the detachment in the sunken way. The men on the stage enter the shot, adjust the rammer, and help to ram home; it takes eight men to ram home a 12·5-inch shot; they apply their force by means of what are termed bell ropes affixed to the rammer. Before firing, the muzzle derrick has to be hinged back, so as to lie on the gun, and it must be raised again in order to load.

Any elevating or traversing, as well as priming the gun, is done from the level of the drum.

It will be seen that the protection for the gun detachment is far from complete, and, in particular, that the actual operation of loading depends on the two men who are most exposed of all.

When the mounting is fitted with an attached loading stage, the projectile in the truck is brought close up to it along the loading way, and after the charge is entered is hoisted to the muzzle by means of the crane on the slide. It is entered and rammed home as before. The traversing is done from the level of the loading way, and the numbers employed at it are therefore screened by the parapet.

Under-cover Loading.—Various systems of loading R.M.L. guns under the protection of the parapet have been experimented with, and have been classified into three, namely, depression loading, pillar loading, and under-cover loading.

The last term is now restricted to systems such as Sir W. Armstrong's protected barbette, in which the loading is done under cover of a casemate, a short description of which is appended.

The term "pillar loading" is applied to the experimental system of loading a 38-ton gun, in which the projectile is placed on a fixed pillar, and the gun is turned round to it to load. The system of pillar loading has not proved particularly successful, principally on account of the time taken to traverse the gun round to the loading position, and to the difficulty of placing the pillar in security when altering old batteries.

"Depression loading" is the term used when the gun is loaded behind the parapet at any point in its angle of training, as with the 64-pounder or 7-inch R.M.L. gun mounted on a 6-feet parapet slide.

A system of "depression loading" was proposed for heavy guns, in which the shot is rammed home by means of a "chain rammer."

The latter is formed by a peculiarly shaped chain, which will coil up in one direction only, so that it can be stowed away under the gun. This also has proved unsuccessful, so that for heavy R.M.L. guns we have had to fall back on the minor improvements before described.

Armstrong's Protected Barbette.—A system of protected loading has been worked out by the Elswick firm, and has been used to some extent by Colonial Governments and others, and to a limited extent in our own service. The essential part of it is a long pivotted trough, in which lie the charge and the rammer, and which is sheltered from fire by the parapet, or is placed in a loading chamber. The gun is turned to one side and depressed about 13° to load, and the charge raised to the muzzle by pivotting the trough; it is then rammed home by working a winch, from which the power is communicated to the rammer by a wire rope.

It certainly gives complete cover to the loading numbers, but there are several points which are very much against it. The chief of these are the following. The emplacement with the loading chamber, even if there be only one, covers a good deal of ground; any superior slope given to the parapet causes the protection to the loading chamber to be dangerously thin, and the possible angle of training is limited by the form of the parapet. It is only 130° with two loading chambers. The gun could be fired at high angles of elevation at angles of training up to 180°, but this would be with the muzzle inside the parapet, and therefore with considerable risk of injury to fittings.

A certain interest attaches to this mode of loading, as the principle is the same as that adopted for the 100-ton guns at Gibraltar and Malta.

3.—CASEMATES FOR R.M.L. GUNS.

The interest of this section is now mainly historical, but as a large number of casemates have been built, and are now in use, it has been reproduced to show how they were designed and constructed.

Emplacements which take Casemate Slides.—Guns on casemate slides are mounted either in masonry casemates with iron shields; or behind open-battery shields, as they are called, though they are often provided with permanent iron overhead cover, which converts the emplacement into a casemate; or behind a continuous iron front; or in curve-fronted casemates which have two ports, and contain a turntable, enabling the gun to be moved from one to the other.

Setting aside the consideration of the ironwork, with which Colonel Inglis has dealt in various articles published in the *R.E. Professional Papers*, the principle of designing all these varieties is the same, namely, to have just enough room to enable the gun to be conveniently worked, and to have all the construction as solid as possible.

Conditions Governing the Size of a Casemate.—The size of the casemate therefore depends on the angle of traversing, on the dimensions of the slide, the position of the traversing and elevating gear, the mode of loading, and the height of the top of the breech of the gun when run back and depressed, in which case it is at its highest.

To Make an Exact Design.—Therefore, in order to make an exact design for any particular gun, it is necessary to get a drawing of the gun, carriage, and slide, to lay down on a plan the extreme lines of fire, which for a shielded gun should not include a greater angle than 60°, and applying the drawing to them to sketch in the masonry around it, just leaving the necessary amount of room.

The minimum height of the casemate above the gun would be determined by drawing a section through the gun run back and depressed, and the remaining dimensions would be fixed by the necessities of the construction.

It may sometimes be necessary to go through this process of design, as, for instance, in the case of a work being built on a restricted site where every inch of space is valuable, and then the lithographs of carriages and slides issued by the Royal Carriage Department will supply the necessary information, but the dimensions and arrangements of the slides for all heavy guns are so nearly alike that, as a rule, it is advisable to build the casemates of the same size for all of them.

Dimensions for a Casemate.—If an arc be struck from the pivot as a centre with a radius of 24 feet 6 inches, and the space within this be kept clear for the gun up to the extreme lines of fire and 4 feet beyond them, there will be floor space enough for any gun up to the 12·5-inch of 38 tons.

For the height, 9 feet is enough for the same guns, and this or a little more to suit the circumstances of the construction is given to emplacements which have iron overhead cover, the height being measured to the underside of the girders. For a 10-inch R.M.L. gun 8 feet is sufficient height.

All the new B.L. guns up to and including the 12-inch B.L. of

47 tons can be mounted in casemates which would take 38-ton R.M.L. guns.

As much free space as possible should be provided in rear of the B.L. gun for convenience in loading. The 12-inch 43-ton B.L. gun requires a space of 8 feet behind the breech when the gun is run up, or a distance of 26 feet 6 inches from the pivot, and it would probably be advisable to leave a space of 10 feet.

It would almost always be necessary to traverse the gun to a central position after each round, in order that the loading may be carried on clear of the rear piers of the casemates.

Arched Casemates (Plate XXXIII.).—Arched casemates must be higher in the centre than those with iron roofs, but the springing can be lower, as the gun must be a little distance from the side wall, and the rise of the arch can be made enough to clear it. A height of 6 feet to the springing and 6 feet more to the crown of the arch is usual, the span being about 22 feet.

The arch of the casemate is sloped down to meet the top of the shield for a distance of about 12 feet, and then the front part where the shield comes must be shaped accurately to fit it.

If the shield frame be set up and the masonry built round it, this is simple enough; if not, the exterior dimensions of the shield to be used, which of course would be known, must be very carefully followed, as the power of the work to resist displacement under the blows of heavy shot materially depends on the mutual support given by the masonry and ironwork.

Size of Curved-top Shield.—Shields for single tier masonry casemates having arched roofs are made 11 feet 11½ inches wide and 9 feet high in the centre with a curved top, so that the ends are 7 feet 6 inches high. The masonry opening is 12 feet wide, 9 feet high in the centre, and 7 feet 6 inches to the springing.

The shield for a double tier work, of which there are two examples, may simply be considered, so far as the masonry goes, as a single tier shield stretched out to cover the ends of two casemates and the floor between them.

Result of the Constructional Requirements of an Arched Casemate.—It is found that the triangular space required by the gun cannot be conveniently arched without the use of cross arches and groins. The use of the cross arch results in the construction of a passage running parallel to the front of the battery, which is very convenient for communication and for the service of ammunition, and also gives a little spare space near the gun where projectiles can be stored ready to hand, and where the range-dials, by which the ranges are signalled to the guns, can be read. But this cross arch limits the thickness of the piers, and consequently their power to resist projectiles.

The width of the shield is also limited when used with masonry casemates by the desirability of not having too high an arch over it, as such would uselessly increase the height of the shield, and afford a larger mark to the enemy.

The result of these two causes is that in a masonry casemate the piers cannot be very thick, and must have their inner corners taken off in a way which reduces their strength at the junction with the shields.

Iron Overhead Cover (*Plate* XXXIV.).—Iron overhead cover enables one to obtain more strength by allowing a greater width of shield to be used without at the same time adding to the height, and by setting one free from many constructional difficulties in the roofing.

The latest development of the shield with iron overhead cover is exemplified in the battery shown on *Plate* XXXIV., in which the shields are 20 feet long, and 11 feet high externally, and the piers between them 36 feet long and 20 feet thick.

The cross passage, which still exists, is reduced to a width of 6 feet and comes quite at the end of the platform; about 3 feet in depth only is cut off the corners of the piers.

The arrangement of the guns and the great length of the piers in this battery were necessitated by the conditions of existing work in the ammunition stores and foundations. If it had been a new work it would probably have been more economical, and would have given greater strength against attack, to adopt a continuous iron front; but the plan is a very convenient one.

Behind each pier is a casemate fitted as a barrack-room, and the casemates immediately behind the guns are kept quite clear of everything, so that the ammunition service from the lifts which open into them is no way hampered, and the guns can be kept always ready for action.

The great mass of the piers is a very good feature; a heavy shot entering a block of masonry not only penetrates directly into it but also wedges the stones apart, shaking any small construction to pieces, and this effect can only be opposed by weight and solidity, which is greater in this case than in the older casemated batteries.

Open Battery Shield.—A commoner form than the above, and one

which has some advantages from a defensive point of view over the masonry casemate, is the open battery shield with permanent overhead cover. The title sounds rather contradictory, but all the open battery shields are designed to be covered in case of need with timber or iron, and in many cases the iron protection has been supplied and fixed.

The advantage of this form is that it gets rid of the masonry arch over the shield, which is a weak point, and is liable to be brought down in front of the gun, and also reduces the total height of the work, so that there is less to aim at and to hit.

The shield is flat-topped, with dimensions similar to the casemate shield, that is, usually 12 feet wide and about 8 feet high, and a roofing plate, 2 inches thick or so, is carried back from it for about 6 feet; the rest of the emplacement is roofed with girders and buckled plates, the whole being covered with concrete.

In plan the emplacement is like a masonry casemate, but the cross passage behind the piers is no longer absolutely necessary, so that the work can be made stronger and be more easily adapted to restricted sites.

Arrangement of Roof Girders.—Without going into the details of the ironwork, it should be observed that the roof girders are placed perpendicularly to the face of the shield so as to give it support when struck; the rear ends of these girders should, if possible, be supported in their turn, and it is best to adopt an arched construction for the back of the casemates, the girders being abutted against the ends of the arches, as shown in *Plate* XXXIV.

If there be no building in rear, or if the arches there be too high to take the ends of the roof girders, the latter are carried on a cross girder, and in order that this may be of moderate dimensions it is often supported at several intermediate points by iron piers, one of which can be removed for a time to admit of the introduction of the gun.

Continuous Iron Front.—The best protection is given by the continuous iron front, such as is used in the large sea forts at Portsmouth, Plymouth, and Portland.

Constructionally, this is an extension of the system just described. A wall of iron plates forms the front of the battery; these are supported, and the roof girders carried, by piers of iron and concrete. The roof girders abut against a row of casemates; the whole is covered with concrete.

Besides its strength, the continuous iron front has another advantage due to the absence of masonry piers, viz., that the guns can be put at closer intervals than is otherwise possible—about 24 feet from pivot to pivot on a straight face. This may enable a site to be made use of which is too restricted for any other form of casemated battery.

This form of construction can be made capable of resisting modern projectiles by simply adding additional thicknesses of plates for which preparation was made in the original design.

Curve-fronted Casemate with Turntable.—There remains one other form of iron protection, the curve-fronted casemate, which is a device to enable a casemated gun to command a large arc of fire—120° instead of 60°.

It is pierced with two ports, and contains a turntable, by means of which the gun can be changed from one port to the other. The principle is one which has not uncommonly been applied on board ship, but on land there are not many examples.

There is evidently a source of danger in the unused open port.

The construction is that of a shield of large size with iron overhead cover. There is as much iron in it as in two ordinary shields, and the casemate is an expensive one, but economy has been attained by using one gun to command a certain area of water instead of two which would be required if ordinary casemates were used, and there is a saving of space by this arrangement as compared with two ordinary casemates, which has occasionally proved useful.

Casemate Details for R.M.L. Guns.

Casemate Floors and Fittings on them.

Casemate Floors for a Heavy Gun.—The floor of a casemate for a heavy gun must be solidly constructed, as it has to carry a considerable weight, and to resist the shock of recoil. If resting on arches, the total minimum thickness should not be less than three feet.

Usually the whole of the front part of the floor for about 12 feet back from the pivot, and for 4 or 5 feet in front of it, is constructed of large blocks (about 6′ × 3′ × 2′) of granite, or other hard stone, on which stands the shield and the front racers. Before ordering these stones, a drawing has to be prepared to show the exact position of the joints, with reference to the base plate of the shield, and to the front racer, and the sizes of the stones are so

chosen that no feather edges may be produced by a sinking cutting across a joint at an acute angle.

Rear Racer Blocks.—The rear racers are laid on a ring of granite, or hard stone blocks, each about 4′ 6″ × 2′ × 2′, and the space between the stonework, and behind the rear racer blocks, is filled in with cement concrete.

It is especially necessary that the rear racer blocks should be well backed up by 4 or 5 feet of concrete, as if there is the least jump of the slide, the whole force of the recoil is transmitted to the rear racer.

In some of our older works, the rear racers were laid on oak blocks, but these were very unsatisfactory. In cases of emergency, if it were desired to mount a heavy gun in a hurry, a solid wooden platform might be used with the racers spiked down to it, but it could not be expected to last long.

Crossing Plates.—In some works, where the guns are close together, the rear racers intersect, and special crossing plates have had to be used to enable the guns to get their full amount of lateral training.

These are thick plates of steel, prolonging the form of the racers and the sinkings for the flanges of the trucks. Part of the upper surface is roughened to improve the foothold. They are set, like the racers, in granite blocks arranged to suit their shape.

Survey for Crossing Plates.—Each crossing plate had to be designed to suit the position it will have to occupy, and to do it with the necessary exactness a most careful survey of the racers and their intersections was requisite. The centre lines of the racers at the intersection had to be drawn full size, so as to give the exact angle at which they cross, and, besides this, a general survey of the racers had to be very accurately made.

Tested steel tapes were used in taking the measurements, the length of the trammel used for laying down the curve of the racer was perfectly accurate, and the exact distance between the pivots had to be known. This latter is perhaps the most difficult part of the operation, as the distance cannot be directly measured on account of the interference of the armour.

The survey is sent to the Royal Carriage Department, who lay down the plan of the racers to full size in a moulding loft, in order to get the dimensions of the crossing plates.

For further information on Racers see Section 6 of this chapter.

Stops.—In order to limit the amount of traversing of the gun without allowing it to strike the piers or shield, stops are affixed to the rear racers. With flanged racers these are small studs, of the height of the racer, screwed into the flange: with solid racers, such as those for the 38-ton gun, they are simple steel blocks, let into the stone alongside of them. (See litho. accompanying I.G.F.'s Memo. on $\frac{\text{Genl. No. 5.}}{563.}$, dated 25th October, 1877).

No Actual Pivots.—It will be noticed that there are no actual pivots used in casemates; the reason of this is that the necessity for putting the position of the pivot far forward, in order that the size of the shield opening may be a minimum, would make it impossible to secure an actual pivot against the chance of injury from a shot striking the shield; and as, if displaced, it would prevent the gun being traversed, it is thought better to omit it altogether, and to take up the recoil entirely by the racers.

Considerable inconvenience has been caused in connection with position finding by the absence of actual pivots. In consequence of the want of any means of accurately centering the slide when being traversed, it is apt to get slightly askew, and not always to lie on the bearing indicated on the training arc. At long ranges this is serious, and it is possible that in some cases a form of parallel motion will be fitted to the slides, which will keep them always truly radial to the imaginary pivot.

Training Arc.—Besides the racers there is on the floor of the casemate the brass training arc for use in position finding. (See I.G.F.'s Circulars, No. 292, dated 1st November, 1879, and No. 516, dated 2nd May, 1887, for the newer patterns of arc).

Traversing Racks.—In the case of the 38-ton guns, there are also the cast iron traversing racks. (See I.G.F.'s Circular, No. 250, dated 26th September, 1876).

Both these may be fixed in concrete or stone, whichever they may happen to come upon.

When a crossing plate interferes with a training arc, the graduations must be cut on the steel, or the arc let into it.

Ringbolts.—The only other fittings on the floor are ringbolts, which are best fixed somewhere near the ends of the rear racers, two to each gun, or one between each pair of guns. Ringbolts in this position were originally intended to assist in traversing the gun with tackle, and they might serve this purpose again in case of a break-down of the traversing gear, but their use at present is in making fast the tackle employed when mounting the guns. With the 7-inch R.M.L. gun only are they still used for traversing.

The ringbolts should be four inches interior diameter, two inches

thick, and attached to a block of hard stone firmly set in the floor. The stone should be hollowed at top to allow of the ringbolt lying flat on it, and flush with the surface.

If there is no room on the floor, the ringbolts may be set in the walls about one foot above the floor. When merely intended for use in mounting guns, eyebolts may be used without loose rings; in this case the tackle would be attached by means of a rope strap.

Casemate Walls and Fittings on Them.

Casemate Walls and Piers.—The casemate walls or piers are of what was considered the most massive construction that could be conveniently provided, so as to oppose the greatest resistance to displacement. The exterior is built of granite or other hard stone, as the hard face assists greatly in stopping the shot that may strike it. The inner face is formed of ashlar masonry, and the hearting either ashlar or cement concrete. All the stones are set in cement.

Stones which are easily cut have been shaped with hollows and projections to fit into one another, so that they may be difficult to shift.

The shape of the interior of the pier is defined by the room required for the gun, as before described; where the shield comes, it is cut to fit it; the exterior may be either straight or curved outwards in plan, and is usually about 2 feet 6 inches in advance of the face of the shield. This dimension might with advantage have been increased.

The stones about the embrasure should be rounded, and as far as possible shaped so as not to guide projectiles or splinters of stone into the port.

It may here be observed with reference to the embrasure, that the stones in the sole of it just under the muzzle of the gun, if not either very heavy or held down by the shield, are liable to be jumped up by the firing of the gun over them, and they should therefore form a flat invert arch held down by the piers. This precaution is very necessary.

Section of Work.—In front of the casemate the face of the piers is usually flush with the escarp; this is a bad arrangement, as it gives no security against a shot penetrating just under the shield, and disturbing the floor of the casemate and the racers.

Range Dials and Fighting Lanterns.—The only fittings on the piers are the sockets for Tremlett's fighting lanterns, naval pattern, and the range dials by which the position of the ships to be fired at is indicated to the men at the guns. Of the latter, more will be found in connection with position finding in Section 9 of this chapter.

The sockets of the fighting lanterns are little bits of metal shaped to take the flat hook of the lantern. (A drawing will be found in the litho. which accompanied I.G.F.'s Memo., dated 30th October, 1878, on $\frac{\text{Genl. No. 5}}{914}$).

The lanterns are intended to enable the batteries to be fought at night; two of them are allotted to each gun-casemate, and they should be placed so as to afford the best general light for the men working, while at the same time they should not be visible from the exterior. The best place must be determined by experiment in each battery, but, as a rule, this is found to be the side of the pier about abreast of the front of the platform when it is in the centre of the emplacement. The light can be screened from the front by turning round the reflector, which is movable.

Lights will also be required to illuminate the range dials, and for the elevation indicators. In addition to these lamps, the No. 1 of the detachment would be provided with a hand lamp to read the training arcs by, and also other lamps will be required about the battery to give light to the men bringing up ammunition.

Casemate Roofs and their Fittings.

Arched Roof.—The casemate arches are, internally, from about 20 feet to 22 feet span in the rear part, with a rise of 6 feet, and a height at the springing of 6 feet also, so that the casemate is 12 feet high in the centre.

The cross arch may be from 10 feet to 15 feet span, with a height in the centre equal to that of the main arch. In the front part of the casemate, the arch slopes down to meet the top of the shield. There was room for a good deal of variety of opinion as to the manner in which this sloping arch should be built, and how the arch stones and springers should be cut.

The exact arrangement adopted did not much matter as far as the arch is concerned if it were solidly built, but it was necessary to give it careful consideration before beginning the construction. Probably the best way was to make the curve of the sloping arch the same as that of the main casemate arch, and to set the centering

at an inclination to the horizon, and at right angles to the crown; the springing stones being stepped to suit the arch stones. There is, of course, a groin at the intersection of the sloping arch with that over the shield, and several at the intersection of the sloping, main, and cross arches. An elliptical cross section was sometimes used, or a sloping springing; or, what was sometimes a good arrangement, the intersections of the arches, instead of being groined, were ribbed like a Gothic arch. This suited the case of there being a limited supply of good material, which was used for the ribs, and inferior stuff for the filling-in between them.

The front of the arch, as of the piers, is of granite or hard stone, and is carried back, for several feet at least, in ashlar masonry. Brickwork is sometimes used, or concrete with an iron hood in the interior, connected with the shield frame, which serves to support and strengthen the arch.

The external arch stones should be massive; they are usually built in two rings in the manner shown in the drawing (*Plate* XXXIII.), where the correct position of the joints is given, and the intersections of the curves for an arch for a 12-feet shield.

Overhead Loops.—In the arch are fixed two or three iron loops for suspending the gun during the process of mounting it. They are made of bar iron 2 inches diameter, bent into a loop 5 inches across.

The ends are from 4 to 6 feet long, and pass up into the arch and through an iron plate, in size 1 foot 6 inches by 11 inches by ½ inch, on which they rest by means of nuts. The loops are placed on the centre line of the casemate, facing to the side, their positions varying according to the nature and weight of the gun that is mounted, they being at the following central distances from the pivot of the gun:—

For 12-ton R.M.L.,		6′ 6″, and 17′.
18-ton	,,	9′ 0″, and 19′ 6″.
25-ton	,,	6′ 6″, and 13′ 6″ and 19′.
38-ton	,,	6′ 6″, and 16′ 6″ and 22′.

The positions of the loops for any other guns would probably be different, depending on the mode of mounting adopted, and the positions of the centres of gravity of the guns.

Slinging Side-arms.—In 38-ton gun casemates, there are also fittings for slinging the side-arms, as laid down in *List of Changes*, para. 3542, 1st June, 1879. These consist of two small eye-bolts in the arch on the right-hand side, with hooks on the side of the pier, and a loop of tarred rope near the front of the casemate. The heads of the sponges and rammers are put into the loop of rope, and the ends hauled up by tackle attached to the eye-bolts. The tackle is supplied by the artillery.

Exterior of Casemate Roof.—Over the casemate arch should be Portland cement concrete, making up a total thickness of from 4 feet 6 inches to 5 feet from the soffit ; but all are not so strong as this.

The top should be rendered with cement or asphalted, and it is a good thing in addition if the asphalte can be covered with about 3 feet of soil, which would preserve it from deterioration.

Loading Bar.—There is another fitting in a casemate for an R.M.L. gun which is fixed to the shield frame when it is present, but which must be provided in any case—that is, a loading bar.

It is a short, strong, iron bar, fixed over and just in front of the point where the muzzle of the gun comes in recoil, and to it is hooked the tackle which is used in raising the shot to the muzzle.

Fittings to the Shield.—There are two other fittings to the shield which may be mentioned in order to complete the account of a casemate—the mantlets and port bar.

Mantlets.—The mantlets are made of interwoven rope, and are hung up behind all ironwork to prevent rivet heads or such like flying into the work if the exterior be struck. They are of a resisting power which just admits the penetration of a Martini bullet, so that it would come through with hardly any remaining velocity. This would not give much protection against modern rifles. They are of a variety of shapes to suit different forms of shield. The portions close to the gun are made movable, being hung on a bar, so that they can be pushed close up against the gun at any degree of training. They are soaked in chloride of calcium to prevent their being ignited by the blast of the gun. See *Equipment Regulations.*

Port Bar.—The port bar is an iron bar put across the port during the operations of loading an R.M.L. gun, to hold up the end of the rammer stave, and make it easier to manipulate.

Number and Nature of Gun to be Painted up.—On the merlon, or over the shield in some conspicuous place, should be painted up the number and nature of the gun, thus : $\frac{\text{No. V.}}{\text{11-in., 25-ton, R.M.L.}}$

The numbering is irrespective of calibre, and in all cases begins on the right of the battery. (See Regulations for the R.E. Department on *Lettering Emplacements*).

Casemate with Iron Roof.—In the case of a casemate with iron overhead cover, the fittings are exactly the same as for a masonry casemate. The floor is the same ; the piers are built to suit the ironwork, with masonry up to the top of the ironwork, and then the whole area is covered with cement concrete rounded down to the front (see *Plate* XXXIV.). This rounding may be formed with brick set in asphalte, or with asphalte tiles set in cement.

Mode of Loading.

Mode of Loading in a Casemate.—The mode of loading an R.M.L. gun in a casemate is generally as follows :—

The gun being run back, two men stand in front of the muzzle and sponge, receiving the side-arms from the right-hand side of the gun.

The cartridge is then brought up on the left-hand side in its zinc cylinder on a man's shoulder, the lid taken off, the cartridge extracted and inserted into the bore.

In the case of the 38-ton gun, the two half-charges are brought up by two men carrying them by means of bars run through the handles on their lids. The powder is thus much safer from machine gun bullets than when on men's shoulders.

The projectile is then brought up on a shell truck, the latter being made with four wheels, so that it may be got over the racers and racer sinkings ; it is hoisted to the muzzle by means of a tackle hooked to the loading bar, and with the fall taken through a snatch block on the slide, and the two men at the muzzle enter it. They then adjust the head of the rammer, and the whole charge is rammed home with the aid of several of the detachment at the rammer bell-ropes. They then ram home the wedge wad, and the gun can now be run up, traversed, elevated, primed and fired.

It will be noticed that the principal operations of loading are carried on close to the open port ; this is unavoidable with an M.L. gun, and it is one of the principal advantages derived from breech-loading in casemates, that it can be done with the gun run up, and the mantlets closed.

This short description of the mode of loading is given in order to assist in realising the operations, so that the necessary space may be left for them in designing new casemates.

For further particulars, see the *Manual of Siege and Garrison Artillery Exercises.*

4.—GENERAL ARRANGEMENT OF CASEMATE BATTERIES.

This section is partly historical and partly intended to assist in devising means for improving casemated batteries, by describing convenient arrangements for them, and by giving a short account of the alterations now most in vogue.

As a rule casemated batteries are built in two stories, the guns above, the magazines below, and the ammunition is served up through lifts, either behind the merlons or in the rear piers of the casemates.

Position of Lifts.—This arrangement is a convenient one if plenty of lifts be provided, and of these there should, if possible, not be less than one, either for shell or for cartridges, to each gun; that is to say, there should not be more than two sets of men going to the same lift for ammunition.

Much of the convenience of the battery depends on the position of the exits of the lifts with regard to the gun.

The best place for them is in the rear piers of the casemates, as in the battery shown in *Plate* XXXIV. When they are there the necessary manipulation of the shells and cartridges is done in a sufficiently large space and away from the men working the gun, and when they are ready to be brought up for loading they can be taken straight to the point where they are wanted, without any dodging behind the tail of the slide, and without having to serve the gun from the wrong side.

In a great many of our old works, however, the shells are served from the rear and the cartridges from behind the merlons. This is convenient enough, but the space behind the merlons is wanted for so many things that it is better not to occupy it with the ammunition service; moreover, the merlons are liable to be put out of shape by the explosion of shells, or by the blows of projectiles from the smaller armour-piercing guns, or even destroyed entirely by the heavier weapons, so that the lifts there might in this manner be rendered useless, and the fire from the battery much delayed; also an explosion near the head of the lift, which might be communicated to the magazine below, is more likely to occur here, close to the ports, than in the more remote position.

Position of Magazines.—In batteries built on restricted sites or on such as require expensive foundations, placing the magazines under the gun casemates is obviously the best plan to adopt, as it keeps the area of the fort at a minimum.

Protection to Magazines.—The chief difficulty lies in giving sufficient protection to the magazines against heavy projectiles. Not many years ago 14 feet of granite and masonry was considered ample for their security; now we have increased the protection of many magazines to 40 feet, and this is not excessive in the face of the 100-ton gun, and of others which are being produced, and which though of less weight will have quite as much penetrative power.

Arrangement of Magazines.—A convenient plan of magazines would consist of alternate shell and cartridge stores, with serving rooms between them, from which the lifts would pass to the gun floor. The shell stores could be left open to the ammunition passage; the cartridge stores should be closed in, and the doorway hung with a rope mantlet door to reduce the risk of an explosion.

A lamp passage would run along the front of the stores and would light the ammunition passage through the shell stores and serving rooms.

There should be storage for at least 100 rounds per gun. At foreign stations, for 200 rounds.

On the gun floor the lifts would issue in the middle of the rear piers of the casemates. If it were desired to economize by shortening them the lifts might issue in the open air. Part of the covering of the magazine would then lose the protection of the roof of the casemate, but this is not of much consequence.

Alternative Position of Magazines.—In some cases where there is plenty of room for the works, it may be found economical not to place the magazines under the gun casemates, but to keep them independent. In such a case they are best placed on the flanks of a battery, where they can be thoroughly well protected, and where the service of ammunition could be arranged to be entirely on the level of the gun floor, thus avoiding the necessity of lifts. Any arrangement of the ammunition chambers can be adopted that appears convenient, care being taken that the service is easy, and that the men supplying different guns do not interfere with one another. For this reason the shell passage had better be distinct from the cartridge passage.

The rule of not allowing more than two guns to depend on one point of issue for shell or for cartridge should always be observed; that is to say, if one magazine has to serve three or four guns, a serving room should be provided with two issue hatches.

Four guns to one magazine should be the maximum allowed.

The application of this arrangement of magazines to a battery with a large number of guns would cause it to be broken up into groups separated by a considerable interval, a disposition which presents various advantages; the casemates would be more difficult to hit than if they were altogether, any injury would be isolated, the superintendence of each of the independent groups of guns would be easy, and there would be less interference from smoke.

Bringing the Guns into a Work.—Room must always be left for bringing the guns into the battery. This question may sometimes come up when designing alterations. If there is any doubt about there being enough space, a cardboard template of the gun can be applied to the plan to test it. In cases where it cannot be done in any other way the guns may be introduced through the roof, which would be completed over them.

Over the entrances of sea forts, where 38-ton guns are mounted, a strong cantilever with hoisting gear is fixed, so that the guns can be raised from a barge and run into the entrance.

Strengthening Casemates.—Forts with iron shields are too numerous, occupy too important positions, and are too heavily armed not to render it inevitable that efforts should be made to retain their fighting capacity as long as possible, provided the cost did not rise so high as to make it less expensive to build new batteries. The following methods have been adopted with a view to doing this:—

Open Battery Shields.—The battery generally might be strengthened in the same way as a barbette can, either by filling up the ditch or by moving back the guns. The shields themselves can be perforated by shot of no very great weight, or displaced bodily by a blow, or turned, so to speak, by a projectile which may penetrate the merlon where it is weakest, near the junction with the shield. This weakness it has been proposed to remedy by reducing the number of guns and by combining three shields into one. The guns are placed further back: each shield is supported on either side by a shield frame and one plate. The remaining plates, which are two or more according to circumstances, are used to thicken the shield; the plate upon plate construction being specially adapted to this operation.

No improvement is possible with the gun, for it is useless adding to its power at long ranges, since the possible elevation is limited by the port in the shield; the mounting also remains unchanged.

Masonry Casemates with Iron Shields.—These are pretty evenly weak all over, and require considerable alterations to make them efficient. A proposal was made by Major English, the Inspector of Iron Structures, which met the case as far as the protection was

concerned, but the cost and the fact that part of the construction is of a somewhat experimental nature, has prevented its being tried. It is, indeed, questionable if such an expenditure as it would involve would not be more profitably devoted to the construction of new works. The idea is to fill up the ditch (an operation, by the way, which usually comes first in any scheme of re-construction at the present time), to increase the number of plates on the shields, and to protect the masonry below, above, and at each side of the shield by large masses of cast iron, weighing nearly 100 tons apiece, curved on the faces in the manner best suited to deflect shot. The idea of the cast iron is taken from Grüson, of Magdeburg, who has made many cast iron turrets and casemates for Continental Powers, but the metal used in these positions, where it is well backed up, is said not to require such skilful casting as is requisite for turret armour. It would, however, be necessary to set up a special foundry to cast these enormous blocks.

In places of inferior importance, various minor reforms can be carried out. The ditch, of course, can be filled up when there is one. Additional protection is thus given to the ammunition stores, so that there is no longer the risk of having the whole fort blown up by one unlucky shot, and the weak point just under the shield is strengthened. To do this as effectively as possible, the earth should be carried up as high as the sill of the port in the shield. Some will be blown away by firing the gun, but enough will remain to make the protection to the stonework better than if it was not carried above the base plate. It would be better to add a mass of concrete or masonry at this point. It may be noted that these masonry forts, even without ditches, will be fairly secure against assault. They must be stormed either through the ports, which will have shutters or be partly closed by the gun, or over the top, which is 15 feet high, and requires ladders. Where there is no counterscarp, the magazines can be made safer by filling in their outer ends with concrete, and so increasing the thickness. This is better than being blown up, but is not satisfactory in several ways. The ammunition storage is decreased, the protection is not so good as when a sloping surface is presented to the projectile, and nothing is done for the masonry under the shield.

In the casemates, occasional guns can be removed and the space filled with concrete or some other material, forming a traverse. This would isolate any injury that may be received to a section of the fort, but it does not give any additional protection for the guns against shot striking the pier near the shield, since the masonry must be sloped away to allow the slide to traverse. Neither can it, unless two or more adjoining casemates are filled up, be made thick enough to render the centre of the pier proof against heavy projectiles.

In some instances the ammunition stores have been built on the same level as the gun floors. As it is then usually impracticable to thicken them sufficiently, new stores are sometimes constructed at a lower level. By digging these out under the old ones, the latter can be utilised as serving rooms. Convenient arrangements are somewhat difficult to design, but there is no particular engineering problem involved. Only cartridge stores need be treated in this way.

Concealment.—Casemated batteries should in all cases be coloured, or otherwise made as inconspicuous as possible. The exact treatment depends on the background and surroundings, and in all cases must be decided on locally. The colouring has to be very coarse, as the effect has to be produced at a distance of a mile or more. As examples, Hurst Castle has been painted yellow below and blue above, with good effect. The yellow blends with the sand bank on which it stands, and the blue with the distant background of the New Forest. The batteries at Plymouth are entirely covered with irregular patches of red, brown, yellow and green, which assimilates them to the rocks covered with vegetation which surround them. Here it has been found unadvisable to colour the soffits of the arches over the shields, as it would darken the shadows. One of the Spithead forts, out in the sea, is painted with a black and white chequer. This makes the ports difficult to distinguish when close by, and at a distance blends into a grey. This is sufficient to show the great variety of treatment found necessary.

It may sometimes be desirable to plant trees in rear, so as to break the hard lines of the building, and heaping earth on the roof would have the same effect. The crest of the glacis should be made uneven, so as not to make a hard line along the front of the battery; if the ditch has been filled in, the earth should be heaped up in places against the piers. Other arrangements will no doubt suggest themselves to those who have to carry out such work.

Notwithstanding these devices, the sad fact remains that there are a number of masonry casemates that are practically unimprovable. They may have to be kept up for the present as affording the means of fighting guns which may turn the scale in our favour in an attack, but as little money as possible should be spent on them, and they

should be looked upon as, in a few years, to be as obsolete as the older works which are often to be found in their neighbourhood.

With regard to the guns and mountings, no alterations are proposed for those which are left in the casemates. Any that are removed will find themselves converted into barbettes giving long-range fire.

If the reconstruction with the cast iron blocks, which is to make the casemates proof against the heaviest guns, were carried out anywhere, they would no doubt be eventually re-armed with long B.L. guns. The 12-inch of 49 tons is the largest that will go into one of the casemates.

5.—MOUNTINGS FOR B.L. GUNS.

The armour-piercing guns in the land service are six in number, namely, the 6-inch, 8-inch, 9·2-inch, 10-inch, 12-inch, and 13·5 inch. Of these there are only four 8-inch mounted as a special measure; the 12-inch proposed are all to be in casemates, and it is very improbable that many 13·5-inch will be used. The remaining service guns, the only ones generally employed, are of several marks differing in size and weight, but with regard to their mountings may be considered in two groups—the 6-inch gun in one, the 9·2-inch and 10-inch in the other; for these two guns are similarly treated, and their emplacements differ only in dimensions.

The 6-inch B.L. gun has three species of mountings—the hydro-pneumatic disappearing or H.P., either with or without an overhead shield; the barbette; and the "Vavasseur." They are all pivotted centrally, and can traverse through the complete circle. The gun on an H.P. mounting only shows over the parapet in order to fire; when fired it recoils under cover to be loaded. With the barbette the gun is always visible, but most of the operations of loading it are done on a level 6 feet below the crest. It is provided with a sloping shield carried on the mounting. With the "Vavasseur," which is the naval central pivot mounting adapted for use on land, the gun is also visible. Some protection is obtained from a bullet-proof shield, but the parapet is only 18 inches high. This takes up less room than the others but is more expensive. It can give 10° depression to the gun, and it might be of use in special situations, but it is probable that the barbette will now always take its place.

The 9·2-inch and the 10-inch both have hydro-pneumatic disappearing mountings similar to one another in general character.

There are, however, various patterns of each, due to the fact that experiments have been carried out with them in several different directions with more or less success.

Some of the H.P. mountings have overhead shields; others have not. The H.P. mountings, as a rule, are suited for traversing through the complete circle, but the barbette generally are not. Most of the barbettes have inclined steel shields, and the loading is done with the gun at from $12\frac{1}{2}°$ to $15°$ elevation, so that the detachment work with a considerable degree of protection from the front. These peculiarities require special consideration when designing batteries requiring large arcs of fire, or which are unusually exposed to attack.

Mountings for 6-inch B.L. Guns.

Six-inch B.L. H.P.—This mounting is of a type developed at Elswick by the firm of Sir W. Armstrong, Mitchell, & Co., and applied to B.L. guns of various calibres and weights from two tons to 69 tons.

It consists of a lower carriage with a live ring running on circular racers and held down by clips to a ring bolted to the foundations, and of a top carriage composed of a pair of elevators. The upper ends of these elevators take the trunnions of the gun. Their lower ends are fitted with trunnions which rest in suitable bearings in brackets attached to the front of the lower carriage. Slung by trunnions between the cheeks of the latter is a hydro-pneumatic cylinder, the piston of which terminates in a cross-head attached midway up the elevators. By means of suitable valve gear the air pressure in this cylinder absorbs and stores up sufficient of the energy of recoil to be able to raise the gun from the loading position under cover of the parapet to the firing position above it. The surplus energy of recoil is absorbed by forcing the fluid in the cylinder through a small aperture as in the ordinary hydraulic buffer. The overhead shield, when used, is carried on pillars attached to the lower carriage.

There are four patterns of this mounting in use in the service. Marks I. and III. for the Mark V. gun, and Marks II. and IV. for the Mark IV. gun. Mark V. gun is an early pattern of 6-inch, and Mark I. mounting is the first H.P. introduced. This gun and its mountings are used only at Hong Kong, and will not be repeated. Mark IV. is the service gun. Its two mountings are very similar

but not interchangeable. It will be sufficient to give a description of the emplacement and fittings for the Mark IV. 6-inch B.L. gun on the Mark IV. mounting, and to point out where the others differ from it. For details of the mountings see "R.A. and R.E. Works Committee Report," dated 22nd October, 1887.

Emplacement for Mark IV. 6-inch B.L. Gun on Mark IV. H.P. Mounting.—Plate XXXV.—The combined racer and pivot consists of a steel casting 10 feet $6\frac{1}{4}$ inches in exterior diameter, and about 18 inches broad. It includes the racer proper, the vertical rack on which the traversing gear acts, the clip ring in which the clips of the carriage engage which prevent jump, and the flanges on which bear the heads of the holding-down bolts.

The holding-down bolts, which are numerous, are arranged in two rings and are 5 feet long. They are imbedded in a mass of Portland cement concrete, which should be at least 6 feet deep and 14 feet in diameter. The centre of this mass is hollowed out in the manner shown in the drawing to a maximum radiusof 3 feet 7 inches, and a maximum depth of 3 feet below the under surface of the racer in order to give room for the lower end of the recoil cylinder and to admit of inspection. Careful consideration must be given to the foundations of this mass of concrete on which the truth of the racers depends, and which is exposed to upward stresses from the recoil acting on the clip ring as well as to the downward pressures from the weight of gun and mounting. The surface of the concrete under the racer is made truly level, but outside is banked up against it to a depth of about 3 inches to assist in steadying it. From the racer the surface should be sloped away for drainage. In all-round emplacements this slope may be made as much as 1 in 10, so as to gain about 6 inches additional cover for the recesses and passages. A steep slope would inconvenience the loading operations. The floor of the emplacement outside the concrete drum should be formed with concrete about nine inches thick.

The diameter of an all-round emplacement at the floor level is 19 feet 6 inches. This dimension is carried up to a height of about 5 feet 6 inches, when it is sloped in to a diameter of 17 feet 6 inches, at a height of about 6 feet 6 inches above the floor. This size is retained for a height of 18 inches, that is to a depth of 1 foot $2\frac{1}{2}$ inches below the crest, when it widens out to a diameter of 28 feet 8 inches. The total height of the crest above the under surface of the racer is 9 feet 2·8 inches. The drawing will serve to make this clear. The dimensions are mostly necessary ones, and must be adhered to in construction. The size at the floor level is required to give room for the loading numbers to manipulate the breech and to enter the charge. Headway must be kept for them under the overhang. The latter is intended to reduce the opening which would otherwise be left round the overhead shield, the diameter of which is 16 feet 10½ inches. The sloping away at the top is to allow the muzzle of the gun to come in without touching when fired at an angle of depression of 5°. The muzzle moves in a peculiar curve which has been determined by experiment, and which varies for different guns, mountings, and angles of depression.

In an open-backed emplacement the radius of the front can be 8 feet 9 inches, that is to say it need not be scooped out to form an overhang. The gun then cannot be loaded at the front, but it can still be traversed through the complete circle. The section of the upper portion must be retained and carried round through the whole arc of fire.

In an all-round emplacement it is necessary, in order to admit of the use of the rammer, to form recesses in the back wall. These should be 4 feet deep, 5 feet wide, and not less than 6 feet 6 inches high, and their sides should be radial. They should be covered with ½-inch steel plates, curved slightly and strengthened with angle iron, and with concrete over them. Without some strengthening of this nature the arches would be liable to be broken in by projectiles, as they cannot be given much thickness. The recesses may be 4 or 5 feet apart. It will be seen that the gun can only be loaded in the line of a recess, and if firing is going on in any other line it must be traversed after each round, but this is very easily and rapidly done. The emplacement should be entered through the back of one of these recesses.

The angles of the loading recesses are convenient places for shelves on which to deposit the various small stores, such as wrenches, used in the service of the gun. A hook for the shell tray might also be useful.

Overhead Shield.—The overhead shield, though forming part of the mounting, is too closely connected with the emplacement to be passed without special notice. It is circular in form with a long slot in the centre through which the gun can pass. The connections at the ends of this slot are small, so that the two halves of the shield are not of much assistance to one another in giving rigidity under blows. It is made of 1-inch steel curved up in the centre, and strengthened at the edge with an angle iron. It is intended to keep

small projectiles out of the emplacement, and has deflected a shell from an 8-inch howitzer striking at a low angle. The edge is 15 inches below the crest. It is of importance to guard this from being struck, and several experiments have been made with iron rings to strengthen the crest with a view to doing so, but they have not shown so much superiority over simple concrete as to make it worth while incurring the expense that they would involve.

When the gun is down, the opening in the shield can be closed with iron flaps, and with an all-round emplacement a door should be hung in the entrance so that the place can be locked up and used as a store for the fittings ; the gun can thus be kept constantly ready for action.

In order to provide and keep up the pressure of air in the elevating hydro-pneumatic cylinder, an air pump has at present to be placed and worked near the gun. A space of 8 feet 3 inches by 4 feet, is required for the men working it, and a surface of 4 feet by 2 feet must be levelled for the pump to stand on. Two small plugs, by which it is steadied, are supplied with it, and have to be fixed at a distance apart of 3 feet 9½ inches. It is probable that in future the air will be supplied to the cylinder from reservoirs kept ready charged. These, as tried, are 3 feet 8 inches long and 9 inches diameter, and contain air at 1,600lbs. pressure. If they are introduced some convenient place will have to be found for the pump where they can be charged.

Mark II. H.P. Mounting for 6-inch B.L. Gun.—There are various minor differences in the details of the mounting between this and Mark IV., but the only points that affect the emplacement are the following: the edge of the shield is 12 inches below the crest instead of 15 inches, and there is a different number of teeth in the traversing rack. This latter peculiarity renders the mountings non-interchangeable. Also the pit below the racer is 6 inches greater in diameter.

Mark III. H.P. Mounting for 6-inch B.L. Gun, Mark V.—This mounting is peculiar to Hong Kong, and is adapted to the Mark V. gun. It is similar in detail to the Mark IV. mounting, but requires an emplacement 20 feet in diameter at the overhang, and 22 feet 4 inches below it ; the crest is higher by nearly 4 inches. The shield is consequently better protected, and is larger in diameter.

Mark I. H.P. Mounting for 6-inch B.L. Gun, Mark V.—This mounting is also peculiar to Hong Kong. It differs considerably in detail from the others. It has an actual pivot, and the pivot block, clip ring, and racer are all separate. The diameters of the emplacement are the same as for Mark III., but the height is under 9 feet and the edge of the shield is only 6 inches below it. The general style of construction is the same as for the other marks. As these two patterns of mounting will not be repeated it is not worth while describing them in detail.

Storage Recoil Disappearing Mounting.—A mounting is under trial in which the elastic force necessary to return the gun into the firing position is obtained from a steel spring instead of compressed air. It has the advantages of being always ready for use, and of not being subject to loss from leakage. It was intended that the only difference in the emplacement should be the formation of a hole in the centre of the drum, which would be 5 feet across, and 4 feet 3 inches deep below the under surface of the racer; but it has been found necessary to enlarge this so much, that longer holding-down bolts are required. This will necessitate re-laying the racers, if the mountings be changed.

General Requirements.—In all emplacements three or four ringbolts should be fixed in the walls for assistance in mounting or moving the gun. These should be of 2-inch iron, with the ring 4 inches in interior diameter, and should be countersunk in the wall so as to lie out of the way. They should be fixed about 3 feet above the floor.

Under the front wall of the emplacement is a secure spot where a few small recesses for shell may be conveniently placed. They may be 3 feet 6 inches long, 6 inches deep, and 2 feet high.

Consideration must always be given to providing a secure and convenient place for the dial and firing key connected with the position finder, and for the number who reads it, who must also be able to give directions to the detachment. In an open emplacement the corner of the traverse is usually the best place. In an all-round emplacement one of the loading recesses might do, or a recess made off the entrance passage. This subject will be further treated of in Section 10, on Position Finding. The training arc will be 5 feet 10 inches in radius, and the pointer will be on the centre line of the carriage, in the front.

Reverting to the parapet, it may be noted that a simple drip moulding can be made for the overhang by setting a strip of common hoop iron in a groove so as to project about ½-inch, and cementing it in.

With regard to the thickness of the concrete portion of the parapet, it should not be less than nine feet from the face of the

overhang, which dimension is obtained in the following way:—The slope above the overhang is 2 feet 7 inches wide; the muzzle of the gun in the firing position will project about six inches beyond this; say three feet in all. Five feet should be allowed in front of the muzzle on account of the blast, and at least another foot to enable the concrete to be sloped down at its outer edge instead of ending abruptly in the superior slope. If not sloped down in this way even the smallest projectiles striking short will scoop up fragments of concrete, while the slope will deflect them.

Barbette Mounting, Central Pivot, for 6-inch B.L. Gun.—This mounting consists of a carriage, which supports a light inclined steel shield, and which runs on live rollers on the slide. The latter rests on a live roller ring, which runs on a combined racer, rack, and clip ring. There is no actual pivot, or rather the live roller ring, being a complete circle, enables the racer to fulfil this function. The racer is held down by a ring of bolts, which are about six feet long, and are disposed on the circumference of a circle 8 feet 1 inch in diameter.

The slide is prolonged at the rear into a small platform, from which the gun can be laid, traversed and elevated, the numbers standing on it being covered from frontal fire by the shield attached to the carriage.

The racer is 9¼ inches deep, and its upper surface is 4 feet 9 inches below the axis of the trunnions of the gun in firing position. The drum of concrete on which it stands, and which contains the holding down bolts, is 12 feet in diameter, and emerges 2 feet 6 inches, about, above the ground, thus leaving a sunken way between it and the parapet. From this sunken way the traversing and elevating can be done equally well as from the platform attached to the slide. This would be convenient in connection with position finding.

The radius of the parapet through the arc of fire of the gun is 10 feet. This allows the muzzle to project one foot beyond the crest in the firing position, and at the same time is sufficient to clear the whole of the slide, and thus to permit of all-round traversing.

Allowing for firing at 5° depression, the crest of the parapet above the upper surface of the racer is 3 feet 3 inches, and consequently 6 feet 4 inches above the sunken way. For firing at 7° depression the parapet should be four inches lower.

The minimum thickness of the concrete part of the parapet is seven feet. In plan it must be carried in a circular form through the whole arc of fire, on account of the small overlap; past this it should be sloped away so as not to catch projectiles. An all-roun emplacement is possible, but this, which is always objectionable, i specially so in the case of a barbette gun, which is thus liable to b exposed to a lateral fire. Recesses for shell can be formed in it, a in the H.P. emplacement.

Three or four ringbolts should be fixed in the parapet wall, a about three feet above the ground, as in other emplacements.

Care must be taken to drain the space within the racer, which must be kept about $1\frac{1}{2}$ inches below its upper surface, in order to clear part of the live roller ring.

The training arc will be 5 feet 4 inches radius, and will be fixed on the top of the drum. The pointer will be attached to the left side of the slide towards the rear. The elevation indicator is also on the left side of the carriage.

Vavasseur Centre Pivot Carriage, Mark II., for 6-inch B.L. Gun.—This is a naval mounting adapted for land service. It is extremely compact, owing to the short recoil of only 18 inches. It consists of a small carriage and slide, working on a combined racer, rack, and clip ring, as in the barbette mounting, but the diameter of the ring of holding-down bolts is only 5 feet $1\frac{1}{2}$ inches. Since the axis of the trunnions in the firing position is only 3 feet 5 inches above the top of the base plate of the racer, and as the gun has to be worked on the level of this plate, the emplacement becomes an extremely simple one. The parapet, struck to a radius of 7 feet 6 inches, is only 18 inches high, admitting of fire at 10° depression. The floor of the emplacement is a mass of concrete thick enough to take the holding-down bolts, which are about six feet long, and heavy enough to withstand the violent recoil.

The mounting is suited for high sites, where its situation would give it some protection, but it has not been much used, and probably in future the barbette would be taken in preference.

Mountings for 9·2-inch and 10-inch B.L. Guns.

As before stated, the mountings for these guns are similar in character, differing only in dimensions, and it is therefore convenient to describe them together.

Hydro-pneumatic Mountings.—Of these there are three natures; the Elswick (E.O.C.); the Easton & Anderson; and the Royal Carriage Department (R.C.D.). For the first a large number of emplacements have been prepared; of the second there are only two mountings in existence; it is probable that these will be utilized, but that no others will be made; of the third a few are in hand, but it is as yet uncertain to what extent they will be introduced.

The nature of the E.O.C. mountings for the 9·2 and 10-inch B.L. guns is the same as that for the 6-inch, and the general description of one will serve for the others. Besides the increase in the dimensions, the most noticeable difference in the appearance of the larger mountings is due to sinking the racers and the greater part of the lower carriage in a pit below the general level of the floor of the emplacement. This is done in order to load conveniently without having to lift the gun through an unnecessary vertical height. The traversing and elevating is, however, done from platforms attached to the carriage on either side at a level a little above the racers. Thus the men appear to work in small pits.

E.O.C. Hydro-pneumatic Mounting for 9·2-inch B.L.—There are three marks of 9·2-inch gun in the land service, I., IV., and VI. The two latter differ very slightly in dimensions, but Mark I. is a good deal shorter. (See Chapter IV., Section 2). They all, however, go on the same mounting and into the same emplacement, for some alterations to the overhead shield are removable, and the crest of a Mark I. emplacement merely requires the concrete to be trimmed away to suit Marks IV. or VI.

In an all-round emplacement the diameter at the overhang is 32 feet, and below the overhang 34 feet. The height from the floor to the crest is 8 feet $6\frac{3}{4}$ inches, and the lower edge of the shield, if used, is 1 foot $1\frac{3}{4}$ inches below the crest (see *Plate* XXXVII.). In the centre of this there is another pit 14 feet 6 inches across at top, and 3 feet $3\frac{1}{2}$ inches deep, in which is the racer with its surface at that level below the floor. In the centre of this, again, there is a pit 3 feet 6 inches deep, and the same in diameter, to give access to the lower end of the elevating cylinder. There is also a passage round the racer pit to facilitate examination of the live roller ring, clips, etc. The detail of these arrangements can only be understood from the drawing. The combined racer, rack, and clip ring is held down by bolts arranged in two circles, which are, respectively, 9 feet $10\frac{1}{4}$ inches and 12 feet 3 inches in diameter. The bolts are nearly 10 feet long. The concrete drum in which they are imbedded should be at least 22 feet in diameter. It should also be 11 feet deep from the racer, which, therefore, makes it necessary, in constructing one of these emplacements, to excavate to a depth of at least 22 feet below the proposed crest.

The upper part of the concrete portion of the parapet for Marks IV. and VI. guns is sloped up, in a manner which will be understood from the drawing, to its highest point, at a distance of 4 feet 5 inches from the face of the overhang. The diameter of the highest part of the crest of the emplacement is, therefore, 40 feet 10 inches. The muzzle of the gun in the firing position will be just beyond the crest. The concrete should extend about 7 feet 6 inches beyond this, to take the blast, and should be sloped down for about two feet more, giving a total thickness of about 14 feet. For a Mark I. gun the sloping off of the interior crest is very slight, being only an incline of 1 in 3 for a distance of 1 foot 7½ inches.

In an open-backed emplacement it is not necessary to hollow out under the overhang, that is, the front of the emplacement can be formed to a radius of 16 feet. This radius must be carried round through the whole arc of fire.

Round the front of an emplacement recesses should be formed to store projectiles and to shelter the men. They may be 4 or 5 feet wide, 4 feet high, and 2 feet deep, and some might be fitted with seats.

The back of an all-round emplacement should be provided with loading recesses, which should be 5 or 6 feet wide, 6 feet 3 inches high, and are made 7 or 8 feet deep, the back of the recess being at a distance of 24 feet from the pivot. Ringbolts should be provided as is usual in all emplacements.

The training arc is of 7 feet 2½ inches radius, and the pointer is fixed in the front of the mounting.

For details of the mounting see "R.A. and R.E. Works Committee Report," No. 98, dated 20th July, 1888.

E.O.C. H.P. Mounting for 10-inch B.L. Gun.—There are three marks of 10-inch B.L. in the service, I., II., and III. Marks II. and III. are identical in length, but Mark I. is a little shorter in front of the trunnions. They can, however, all go on to the same mounting and into the same emplacement, with a slight modification to the overhead shield. The general arrangements are exactly similar to those for the 9·2-inch, the differences being only in dimensions. Thus the diameter of the emplacement at the overhang is 34 feet 6 inches, and below it 37 feet 6 inches. The height from the floor to the crest is 12 feet 4½ inches, and the lower edge of the shield is 1 foot 10 inches below the crest. The racer pit is 15 feet 4 inches across at top, and 3 feet 6½ inches deep; the lower pit is 4 feet wide and 4 feet 1½ inches deep. The diameters of the circles on which the

holding-down bolts are set, are 10 feet 9 inches and 13 feet 4 inches respectively. The bolts are nearly 10 feet long. The concrete drum should, therefore, be at least 24 feet in diameter, and 11 feet deep, and the excavation must go down to a depth of at least 23 feet 6 inches below the proposed crest.

The crest is sloped out in the manner shown in *Plate* XXXVII. to a distance of 5 feet 3 inches from the face of the overhang, so that the diameter of the highest part of the crest of the emplacement is 45 feet.

The loading recesses need be only 4 feet deep, the back of the recess being 23 feet from the pivot.

In other points the 10-inch emplacement agrees with that of the 9·2-inch.

Easton and Anderson H.P. Mountings for 9·2-inch and 10-inch B.L.—There is one mounting of this pattern for each of these guns which will probably be used but not repeated. It is quite different in appearance to the E.O.C.; the elevators being bent levers and the H.P. cylinders being laid horizontally between the cheeks of the slide. It is not suited for an all-round emplacement, and has no overhead shield. There is an actual pivot, and the racers, which are of a light section, are laid in a circle of 27 feet diameter for the 9·2-inch, and of 29 feet diameter for the 10-inch. This gives a long base for the mounting so that there is no tendency to jump. Consequently the racers and pivot are only held down by bolts 4 feet 3 inches long. The floor of the emplacement outside the racers is raised to admit of more convenient loading.

The leading dimensions of the emplacement will be as follows for a 9·2-inch and 10-inch respectively :—

Radius at overhang, 15 feet 6 inches and 17 feet.

Radius below overhang, 17 feet 6 inches and 18 feet 6 inches.

Height above racer level, 13 feet 7½ inches and 13 feet.

The parapet should be at least 10 feet thick. The other H.P. emplacements should be followed in the matter of the provision of recesses and ringbolts.

R.C.D. H.P. Mounting for a 10-inch B.L. Gun.—This mounting resembles in general arrangement the E.O.C. H.P. for the same gun, but differs from it in many important particulars. In the first place the mounting has an actual pivot which takes the stress of the recoil. This is an "hydraulic" pivot for ease in traversing. The pivot and racer bed are combined into one large casting, the mass of which, together with that of the gun and carriage, is sufficient to prevent any "jump." There are no clips or clip-ring. There is an arrangement of parallel motion intended to prevent any side strain being brought on the piston of the hydro-pneumatic cylinder tending to damage the glands. The elevating gear is also carried by a similar arrangement. The gun, instead of being carried directly by the elevators, rests on a small carriage and slide, which are supported by the elevators and by the elevating gear. The gun on being fired is therefore capable of recoiling to a short distance independently of the disappearing arrangements, and the stress on the latter is thus reduced.

The emplacement may be described as being in two parts: an upper part 36 feet in diameter and 9 feet 9 inches deep, and a lower part sunk in the floor of the first 29 feet 3 inches in diameter and 8 feet $3\frac{1}{2}$ inches deep. The pivot plate, 23 feet in diameter and 2 feet 7 inches deep at the edge, stands in the lower pit, of which its upper surface forms part of the floor. The mounting carries a deck at the level of the floor of the upper part. Below this in the lower pit the traversing gear is worked, and above it the gun is loaded.

The pivot plate is sufficiently massive not to require any assistance from concrete except in the matter of foundations, as it weighs 45 tons. It is made up in six pieces for convenience in handling, but even so it will be a matter of some difficulty to set such a mass with the perfect accuracy demanded.

The crest of the parapet for a distance of 2 feet 6 inches from the interior is sloped down at $\frac{3}{4}$ to allow of the muzzle coming in when fired at 7° depression. This is to suit the Mark III. 10-inch B.L. gun.

The mounting is not provided with an overhead shield, but otherwise could be used in an all-round emplacement. In this case the loading recesses in rear should be about one foot longer than with the E.O.C. H.P. on account of the gun coming down in a slightly different position. Shell recesses and ring-bolts will be required as for other mountings.

E.O.C. Barbette Mountings for 9·2-inch and 10-inch B.L. Guns.—The E.O.C. barbette mountings are almost identically the same for the 9·2-inch and 10-inch guns, and one description serves for both. The mounting consists of a carriage and slide not differing materially in appearance from those of M.L. guns. The carriage is on live rollers, and is held run back for loading by a catch on the slide. It carries a sloping shield of thin steel, 11 feet wide, which starts from a level one foot below the crest and runs up high enough to cover the men

manipulating the breech when standing on the platform arranged for them between the girders of the slide. The slide is a high one, 6 feet $1\frac{3}{4}$ inches in rear, and it is 21 feet 3 inches long including an attached platform in rear, the pivot being 8 feet 3·6 inches from the front end. It works on a combined pivot, racer, and clip-ring, which is formed of a heavy casting fitted with a wrought-iron pivot pin and steel roller path. This pivot plate, which is 12 feet $4\frac{3}{4}$ inches in diameter, is held down by a ring of bolts about 6 feet 6 inches long disposed on a circle 10 feet $8\frac{3}{4}$ inches in diameter. The concrete drum in which these are bedded should be at least 20 feet in diameter for the 9·2-inch gun and 7 feet deep, as the upward pull on recoil is considerable. It would indeed be advisable to extend it up to, but not, in my opinion, beyond the inner wall of the parapet. If in one piece with the concrete portion of the parapet, a large irregularly-shaped mass would be formed which would be liable to develop cracks across it, and which would oppose an absolutely unyielding resistance to the recoil, tending to increase the stress on the mounting. It must be admitted, however, that this opinion is not shared by all those who have to deal with the matter. In any case the greatest attention must be paid to the quality of the concrete drum. In fact it should be rather considered as a part of the mounting than a mere foundation, since at the moment of recoil of the gun the force acting on it is an upward and not a downward one.

The pivot plate is bedded to a depth of 7·425 inches in the concrete, the racer, which is on its outer edge, being left at a height of 6 inches above the general level of the floor of the emplacement. The holes in the pivot plate casting should be filled up flush with concrete.

The radius of the front of the emplacement should be 11 feet 6 inches, if it be not wished to traverse the gun through a complete circle. If, however, it be desired to do so the radius should be at least 13 feet 6 inches for the 9·2-inch gun, and 14 feet for the 10-inch. It would, perhaps, be advisable to make it 14 feet 6 inches for both, so as to make the emplacements interchangeable and not to run the dimensions too fine. *Plate* XXXVIII.

Ring-bolts should be provided as for other mountings, and also recesses for projectiles, and for the detachment where thought necessary. The training arc has a radius of 7 feet 9 inches.

The parapets of these guns appear to require a thickness of concrete of from 18 to 20 feet; the inner portion to protect the emplacement, the outer portion to resist the blast of the gun. It is not possible to economize by making any of this a mere slab, for it must be at the very least five feet thick in order to have any chance of resisting the explosion of large shells bursting on it, and it must be well founded in front so as not to crack and give way under the blast. The upper portion of the mass must be of good cement concrete, but this may be carried on inferior stuff. A battery has been designed with a gallery carried round in the hearting of the parapet with the soffit of the arch about on the level of the floor of the emplacement. It is an ingenious arrangement, but the gallery has to be at such a low level in order to get sufficient protection for itself and not to weaken that of the gun, that it can hardly be productive of economy. In some sites, however, the idea might be serviceable.

It may here be noted that the distance in plan from the pivot to the axis of the trunnions is 3 feet 3 inches. This added to the length of the gun from trunnion to muzzle, see Chapter IV., Section 2, will give the path of the muzzle.

Reverting to the interior of the emplacement, the traversing and elevating are done from the floor level. The loading can be done with the gun run up and horizontal, but the normal service method is with the gun run back and at elevation, 15° for the 9·2-inch and from 10° to 12° 30′ for the 10-inch. When in this position two numbers stand on the platform at the end of the slide to open and close the breech and to enter the charge, which is lifted by means of a crane on the side of the slide. They are protected by the gun itself and by the shield. The ramming home is done by six or eight men on the floor of the emplacement. Thus a considerable amount of security is given to the whole detachment. A distance of 25 feet is required to be kept clear from the tail of the platform to allow of the use of the rammer, or say 38 feet from the pivot. It is desirable, but not absolutely necessary, that the ground should be sloped down in rear of the emplacement from about 20 feet from the pivot, for the more convenient handling of the rammer.

E.O.C. Barbette, D Pivot.—Although it is undesirable to mount barbette guns in situations where they will be exposed to fire through a large horizontal arc, yet it is sometimes necessary to do so. It is certainly preferable to do this rather than to restrict their lateral range by traverses, and thus to reduce the number of shots that can be fired at the enemy. Under these circumstances it may be desirable to use the D pivot mounting, which enables the size of the emplacement to be reduced to a minimum. Everything is the same as

with the centre pivot mounting, except that the trucks are arranged to suit a smaller pivot block and racer combined with a detached racer and clip-ring. The pivot block is 7 feet 9½ inches in diameter, and the racer 9 feet 6 inches radius; all held down by bolts to the concrete. A radius of parapet of 12 feet will enable the gun to be traversed through the complete circle, but it had better be made 14 feet 6 inches to allow for getting round the ends of the slide. The gun in a circular emplacement of this radius could be loaded when run up and horizontal, but not when run back and at elevation, for which purpose a space of 25 feet must be left clear behind the platform.

In this mounting the distance in plan from the pivot to the axis of the trunnions is 6 feet 4 inches.

R.C.D. Barbettes.—These are intended to be the same for 9·2-inch and 10-inch, the emplacements having the same dimensions. There is some uncertainty as to the exact nature of the details that will be finally adopted, various modifications having been made in them since one was tested with a 9·2 inch gun, but a description of the latest arrangement for a 10-inch gun cannot be far out. *Plate* XXXIX.

The leading principle of the design is that it should in no way depend on the concrete foundation of the emplacement for resistance to jump. The mounting is consequently a very heavy one, nearly 37 tons for the 9·2-inch without the gun; the recoil is very long, 8 feet; and the racer, which is a circular one, is 10 feet 10 inches in radius. The desired result is certainly attained, for there is no jump at all, and no clip racer has to be provided. With the experimental mounting the traversing was very heavy, and consequently in the improved pattern an "hydraulic pivot" has been introduced with a view to render it easier. This pivot is in effect an hydraulic jack, and by pumping it up a small distance the weight of the mounting is taken upon it, and can then be easily moved. It may be noted that the gun and mounting must balance on the pivot during traversing, and this is arranged to be the case when the gun is run up. The carriage is a live one, which runs up after firing. The slide is 23 feet long and about 7 feet high in rear.

The pivot consists of a large casting, to which eight cast iron ribs are attached by bolts. On the ends of these ribs rests the racer, which is in addition held down by a number of bolts about 4 feet 6 inches long to the concrete foundation. These appear to be superfluous, as there is no upward pull on the racers. The concrete in this case is merely a foundation. A further peculiarity about this mounting is that the pivot takes no part of the recoil, which is all arranged to be borne on the racer. The pivot merely centres it for traversing. As a consequence of this means have to be adopted for keeping the mounting on the racer against the jerk of running up the gun. This is done by providing a couple of vertical rollers, which press against the back of the racer, and a space at least 10 inches wide has to be kept clear for them to work in.

The radius of the emplacement should be 14 feet 6 inches, which will allow of traversing all round. The height of the parapet for 5° depression should be 8 feet. The floor of the emplacement should be kept at the level of the top of the flange of the racer, sloping down a little towards the pivot to give room for part of the traversing gear. The distance in plan from the pivot to the axis of the trunnions is 8 feet 10 inches for both guns; from this can be determined the path of the muzzle. Ring-bolts, recesses, etc., are provided as for other emplacements.

The loading is done at 15° elevation with the gun run up; two numbers standing on a platform within the slide to manipulate the breech and to enter the charge. Traversing and elevating are done from the level of the floor of the emplacement. The training arc has a radius of 11 feet 11 inches.

8-inch B.L. Barbette Mountings.—These guns will be met with on land works only at one station. They are mounted on a live carriage and low slide. The pivot and racers are carried on a drum of concrete, and have no holding-down bolts, the racers being set on stone. The radius of the drum is 6 feet 9 inches. A clear space of 11 feet 6 inches is required to enable it to traverse through the complete circle. This could be given it, as the radius of the path of the muzzle in the firing position is about 16 feet 8 inches; but, as a matter of fact, the emplacements will not admit of this, having been made in various special forms. The parapet is 6 feet high above the sunken way, running round the front of the emplacement. The loading is done with the gun run back, and at 12½° elevation.

Colonial Mountings.—In our large Colonies, which have carried out works of defence on their own account with an amount of enterprise in which they have been imitated only at a distance by the mother country, various mountings and patterns of guns will be met with other than those described here. The barbettes and H.P. mountings, however, do not differ in principle, but in detail only; indeed, they have in many cases served as the precursors of those in the service. The B.L. mountings have all, up to the present,

been obtained from the firm of Sir W. Armstrong, Mitchell & Co., as well as some long R.M.L. guns which are arranged for under-cover loading. Any service R.M.L. guns that they may have are on service mountings. Although some of our officers will have to deal with them, it does not seem worth while to enter into a description of them here as it would benefit only a few and the principles, as has been said, are identical.

Casemate Mounting for B.L. Guns.—The 12-inch B.L. of 46 tons has been put in the Spithead forts into emplacements formerly prepared for 10-inch R.M.L. of 18 tons, and 12·5-inch R.M.L. of 38 tons, and the space is very restricted.

For the 46-ton gun an arrangement has been designed to take up the shock of the recoil, the effect of which was much dreaded when the gun was first introduced. The front of the platform is fixed to two vertical iron beams, framed together, called the "yoke," travelling between "recoil plates," which are like racers in the floor and the roof. The piston rods of the recoil buffers are attached to these beams, so that the shock of recoil is transmitted both to the roof and floor, and the tendency of the slide to jump is done away with. The arrangement has answered very well as a mechanical expedient, and is adopted for service, but it takes up a good deal of room, and is very inconvenient when mounting the gun.

The gun and carriage will go into an emplacement which will take a 38-ton R.M.L. gun, the rear racer being the same, of 21 feet 2 inches radius; the upper "recoil plates" are formed by an arrangement of curved girder work affixed to the iron roof; and the lower "recoil plates" are curved plates set in the granite floor, which must be very solidly constructed, as it has to be a good deal cut about to take them. It may be observed that an iron roof is essential to this mode of mounting. If it were required to mount a gun in an old masonry casemate, an inner framework of iron must be somehow adapted to it, to take the upper "recoil plates."

It is not worth while giving a detailed description of this mounting, as it is very special, and will be sparingly used.

13·5-inch B.L. Gun.—A few 13·5-inch B.L. guns, of 69 tons weight, are approved for mounting at some of our large fortresses. It may be doubted whether all will be supplied, the feeling now being that they are unnecessarily heavy for our requirements; but if used, they will be mounted on an hydraulic disappearing carriage. With this the gun disappears behind the parapet after firing, as with the H.P. mountings, but it is returned to the firing position by hydraulic power instead of by air pressure. Although it is quite possible to use the latter, yet as power had to be employed for loading and lifting ammunition, it was thought better to use it for lifting the gun also, and thus to avoid the difficulties connected with compressed air. The gun would be traversed to a fixed position to load, the loading apparatus being of the "Collingwood" type, described in Chapter IV., Section 4.

The emplacement and its accessories would take up a good deal of room. The gun itself is 36 feet long, and the powder charge is 630 lbs.; large stores would be required, and, in addition, engine and boiler rooms; all to be secure and not to offer a too visible mark to the enemy.

Cupola for 9·2-inch or 10-inch B.L. Guns.—As for some time this was the only mounting for B.L. guns under trial by the Government, and as a good deal has been written about it, it seems as well to give a short account of the construction, although it is most unlikely that a cupola of this pattern will ever be used.

The cupola consisted of a conical armour-plated turret, supported by trucks running on a circular racer and provided with a central pivot. The lower part of the central pivot consisted of a wrought iron cone 8 feet 8 inches high, filled with concrete and secured to wrought iron girders built in to the foundations. The space between the cone and the walls on which the racer rests formed the serving chamber for ammunition. The traversing was done by a capstan in an adjacent bombproof. A wrought-iron ring surrounded the base of the cupola and retained the concrete which formed the superior slope of the emplacement. The gun mounted in the trial was a 10·4-inch B.L. of 26 tons, experimental.

The diameter of the cupola at the bottom was 23 feet 9 inches and at the top 11 feet 7 inches, and it rose six feet above the crest of the parapet. Its weight was 110 tons.

In the experiments it worked fairly well but was found to be too restricted for space internally, and it was agreed that at least 10-inch compound armour should be used to give fair protection. Consequently its cost would be several times that of a disappearing mounting for the same gun. Moreover it took a large detachment to work it, was always visible, and did not protect the chace of the gun any more than a barbette. For these reasons it was not adopted.

If it ever becomes necessary to put coast defence guns under the protection of armour, it is probable that this design would not even form the point of departure for the pattern to be adopted, but that

recourse would be had to the Grüson turret, which is in the shape of an inverted saucer, with a muzzle-pivoted gun, and which is so well adapted to deflect projectiles.

6.—RACERS.

The most important part of a heavy gun emplacement is the racer on which the slide moves.

The facility with which the gun is traversed depends on the truth of the surface of the racer, and the accuracy with which it has been laid; the entire shock of discharge is transmitted to it through the trucks, and has to be resisted by the security of its fixing; and finally, the datum level for all parts of the emplacement is some point on its upper surface, for on the level of the racer, of course, depends the exact height of the gun.

Racers for R.M.L. guns are either of wrought iron or steel. Wrought iron is used for the smaller guns, 7-inch and 9-inch R.M.L., but for heavier guns steel is used, as it was found that long continued firing dented the softer metal. It is also necessary for the 9-inch R.M.L., when fired at angles of elevation up to 35°.

Also for the sake of increased strength, the old flanged form of racer used for guns up to 25 tons weight was developed into a solid steel bar for the 35 and 38-ton guns.

The dimensions will be found in I.G.F.'s Circular, No. 250, dated 26th September, 1876.

Also see the Table of Racers, further on in this Section.

Racer Blocks.—Racers are laid either on stone or concrete, usually the former.

The stone used should be granite, or if that cannot be procured, a hard limestone or perhaps sandstone. The blocks are usually laid in a polygonal form, following generally the curve of the racer, and in setting them it is necessary to be careful that the racer does not lie too near the edge of the stone. Before ordering the stones a plan of the racers should be made on a good large scale, and the racer blocks drawn on it, so as to get the best dimensions and the joints in the right place.

Rear racer blocks for the 10-inch gun are usually about 5 feet by 2 feet by 2 feet.

In shielded emplacements a floor of granite blocks is often provided, on which the shield and the front racer rest.

Here care should be taken not to let the racer cut across a joint at a very acute angle, as any feather edges of stone are likely to be broken.

Racer blocks must be firmly and truly set, and their upper surfaces should be carefully levelled; for the racer, which has to resist the shock of recoil, is supported solely by being sunk a short distance into the stone. If the top of the stone be not level there must be places where this support is less than it was designed to be, and at a weak place such as this, the stone might flake away under the effect of continuous firing.

Racer Sinking: Setting out.—After the blocks are set, the sinking for the racers should be cut.

It should be set out, not by a tape or measuring rod, but by a wooden trammel made to the radius of the racer and carefully tested.

In the case of a barbette emplacement, a plug must be made to fit into the pivot with the exact centre marked on it.

In a shielded emplacement a little hole should be drilled in the iron at the position of the imaginary pivot, which will serve as the centre of the trammel, and in the future as the datum point for various other measurements.

In an emplacement which requires but has not yet got a shield, the imaginary pivot must be localised as nearly as possible.

It is usually eight inches inside the front of the front plate of the shield, and the proposed position of the front plate will, of course, be known; but large masses of ironwork are never exactly true, and the proper position of the pivot when the shield is put in, is pretty sure to be found different to what it was assumed to be. Then it is necessary to cut the ironwork about the port to get the proper training for the gun. This is one of the troubles incident on building a work without its shields and inserting them afterwards.

The trammel must be made so as not to bend or twist, or it will not give the true radius.

The W. O. litho. which accompanied I. G. F.'s Memo., dated 21–11–77 in $\frac{\text{Genl. No. 5}}{586}$ is a drawing of one used for setting out the 38-ton gun racers for the Spithead forts, and may be adapted for other places.

Cutting the Racer Sinking.—Having set out the sinking, it should be cut by a good mason, who had better be paid by the day and not by the job, so that he shall have no inducement to hurry his work.

The sinking should be slightly undercut so that the mixture of four parts lead and one part zinc, erroneously called an amalgam, with which the racer is run in, may get a good hold. The mixture is used instead of pure lead as being harder.

The bottom of the sinking should be as level throughout as it is possible to get it, and no deeper than is actually required.

Any little hollows left under the racer mean that the latter is unsupported at those points, unless the mixture of lead and zinc when run in completely fills it, and of its doing this it is impossible to make sure.

The proper depth below the pivot to which the sinking should be carried is found by levelling the top of the trammel which was used for setting out the racer, and the best way to test the level of the bottom of the sinking is to pour some water into it, which will reveal all the little knobs and hollows.

The racer must now be placed in the sinking, and tested for level with the trammel and spirit level. It will very likely be found that it is not quite true in parts, but has been very slightly twisted or bent; this may be corrected sometimes by putting thin packing pieces of iron under the racer where required to raise it. These are often necessities but are always evils, as preventing the racer from being evenly supported.

I believe that racers are now sent from Woolwich packed in wood cases, so that they arrive in better condition than they used to do when they had no cases and were very roughly treated on being landed from ships.

If the racer be much out of truth and cannot be corrected, a fresh one should be demanded; not that a little irregularity will affect the traversing of the slide, but it will affect the sights and graduated elevating arc of the gun; and an error of $\frac{3}{16}$ inch in curve is enough to interfere seriously with the training of the gun.

The racer will have to be lifted and lowered several times during the process of testing. The easiest way to do it is by means of some pieces of wire round it. Care of course must be taken that they do not touch the stone or the racer would rest on them. Little grooves might be cut to receive them.

In the lithograph attached to I.G.F.'s circular, No. 250, is shown a clip for attachment to heavy racers, which can be made and used if wished.

The racer having been adjusted, it must wait for the arrival of the slide before being leaded in. The slide must be placed in position and traversed round to ensure the fit of the racer and trucks. When this is done, the racer has received its final adjustment and can be run with "amalgam."

Leading in the Racer.—Before doing so it is advisable to heat the racer and the groove in which it lies, so that the melted "amalgam" may not be chilled and set before it has had time to penetrate into all the little crevices. This may be done by heaping it with hot ashes, taking care to sweep them all away again before using the "amalgam."

Iron Chairs used instead of Racer Blocks.—In some localities it is difficult to obtain blocks of stone fit for use as racer blocks, and in such a case the racers may be set on iron chairs in concrete; this has been done for guns up to 25 tons weight, but cannot be done for anything heavier, as the chairs can only be used with flanged racers.

The chairs are of the shape of an inverted U with turned-out ends; they are of wrought iron, one inch thick and generally three inches wide, except when intended to be used at the joints of the racers, where they are six inches wide. For 10-inch and 11-inch M.L. guns they are all six inches wide.

They are one foot deep over all, and have a flat surface seven inches wide at the top for the racer to rest on.

The racers are fixed to them by screws and nuts; the screws are similar to those used in fixing the spuds when the racers are set in stone, but they have to be rather longer and must be specially demanded.

The racers are supplied with the screw holes bored, but the holes in the chairs should be bored on the spot, so as to ensure perfect fitting of the screws.

The best way of setting these racers is to finish the concrete up to the level of the bottom of the chairs; then to fix together the racer and chairs, and to level the whole by packing under the chairs, using a trammel as for racers set in stone. The slide could then be mounted and traversed to test the fit.

When the racer is adjusted, fill in very carefully with rather fine concrete, taking great care that it is close round all the chairs and comes well up underneath the racer. The concrete must be allowed plenty of time to set before mounting the gun.

What is said here about racers applies equally to barbette and casemate emplacements.

Setting Unflanged Racers on Concrete.—Some racers in our iron forts are set in a channel iron bent to the curve and bedded in concrete. These particular channel irons are in places attached to the iron floor girders, but a similar arrangement might be used for setting unflanged racers in concrete. The channel iron might have chairs or angle irons attached to it so as to have a good hold on the concrete,

and might itself be built up of plate and angle iron. The racer would be leaded into it.

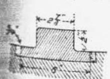
The table and diagram given herewith shows the nature and radii of the racers for each gun.

Table of Racers for R.M.L. Guns.

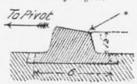
Nature of Gun.	Description of Slide.	Description of Racers.	Radii of Racers.	
			Front.	Rear.
7″ and 9″ R.M.L.	Casemate A	W.I. flanged	6′ 3″	16′ 6″
,, ,,	Dwarf A	,, ,,	6′ 3″	16′ 6″
,, ,,	Dwarf C	,, ,,	5′ 5¾″ Comp. Circle	
,, ,,	Dwarf D	,, ,,	9′ 0″	2′ 3¾″
10″ 18-ton R.M.L.	Casemate A	Steel flanged	8′ 0″	18′ 0″
,, ,,	Dwarf A	,, ,,	8′ 0″	18′ 0″
,, ,,	Dwarf C	,, ,,	5′ 8″ Comp. Circle.	
,, ,,	Dwarf D	,, ,,	9′ 0″	3′ 0″
11″ and 12″ 25-ton R.M.L.	Casemate A	,, ,,	8′ 0″	18′ 0″
,, ,,	Dwarf A	,, ,,	8′ 0″	18′ 0″
,, ,,	Dwarf C	,, ,,	5′ 8″ Comp. Circle.	
,, ,,	Dwarf D	,, ,,	9′ 0″	3′ 0″
12″ 35-ton R.M.L.	Dwarf C	Steel solid	5′ 8″ Comp. Circle.	
12″·5 38-ton R.M.L.	Casemate A, 6′ recoil ...	without	10′ 2″	20′ 2″
,, ,,	Casemate A, 7′ recoil ...	flanges	10′ 2″	21′ 2″
,, ,,	Dwarf A, 7′ recoil	,,	10′ 2″	21′ 2″
,, ,,	Dwarf C, 6′ recoil	,,	5′ 8″ Comp. Circle.	
,, ,,	Dwarf D, 6′ recoil	,,	8′ 0″	3′ 8″

SECTIONS OF C PIVOT RACERS.

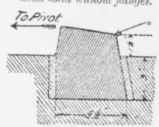
Wrought iron flanged.



Steel flanged.

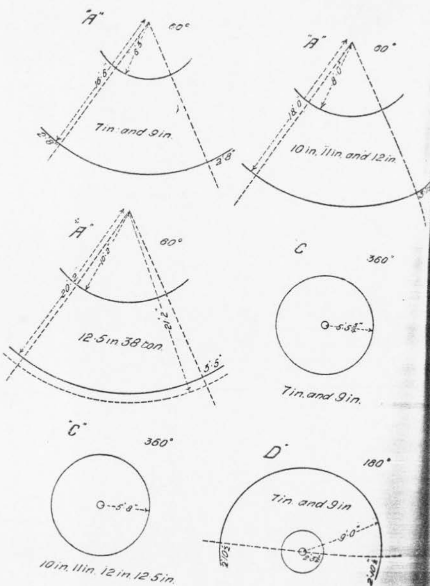


Steel solid without flanges.



* All vertical dimensions are to be referred to this point.

DIAGRAM OF RACERS FOR HEAVY R.M.L. GUNS.



Iron Chairs for Racers.—The following table gives the number of wrought-iron chairs required for fixing in concrete the various descriptions of flanged steel racers for 9-inch and 10-inch R.M.L. guns.

Letter of Racer.	Arc of Training.	Number of Chairs Required.			Remarks.
			Large.	Small.	
A	70°	Front	1	16	
		Rear	2	26	
		Total	3	42	
C	Complete Circle	Total	4	36	
D	180°	Front	3	30	D pivot rear racer a complete circle.
		Rear	2	18	
		Total	5	48	
D	360°	Front	7	49	
		Rear	2	18	
		Total	9	67	

Racers and Pivots for B.L. Guns.—The B.L. guns are mounted either on a pivot and racer, or on a racer only, or a combined pivot and racer. When the racer only is used it practically takes the part of a pivot as well, the horizontal shock of recoil being transmitted to it through steel clips on the slide.

All these fittings are very much heavier than those used for M.L. guns. For instance, the combined pivot and racer with holding-down bolts for a 9·2-inch B.L. barbette, of the Elswick pattern, weighs over 10 tons. It is evident that the problem of handling this weight is one that requires consideration, and in some situations would be difficult of solution. It is made in two pieces for convenience of transport, but it must be put together before being set.

The racers and pivots are nearly all held down by bolts passing through them and imbedded in concrete. The bolts are of various lengths up to 10 feet.

The exact manner of fixing them must vary with their form and dimensions, but the principle with all is the same. It is to put them together, bolts and all; to support the whole system in its true position, and then to concrete it in.

In the case of the combined pivot and racer, the best method of support is to build up a central column of less diameter than the ring of bolts, and to rest the ironwork on it, carefully levelling it. The bolts can then be concreted in, fine concrete being carefully packed under the outer edge of the ironwork.

The lighter racers can be hung from beams or rested on rails or girders, the latter being removed before the concrete is finished. With these racers it is probably best, after firmly imbedding the bolts, to remove the racers and to finish off the concrete to a true surface before replacing them; and not to pack them underneath, which is a somewhat uncertain process.

A method successfully tried with some 6-inch H.P. racers was to thread three of the holding-down bolts through iron pipes, thereby converting them into legs for the whole to stand on. The racers were then levelled and all concreted in.

When the racer is independent of the pivot it is best to set the latter first, and then to place the racers by means of a trammel, as with M.L. guns.

When racers are carried on ribs projecting from the pivot, as in the case of the R.C.D. barbette for the 10-inch B.L. gun, the pivot might be first set on its base and levelled; then the ribs attached and supported by a wall or props near their outer ends, but clear of the racer; then the racer attached, and the whole levelled and concreted in.

The greatest care must be taken to set these fittings level and true with reference to one another. The finish of the modern gun carriages is considerably greater than that of the old ones, and a corresponding nicety is required in their use.

It is not necessary to test these racers by putting the mounting on them before they are concreted in, as was required with the old ones.

7.—GENERAL ARRANGEMENT OF BARBETTE BATTERIES.

In this section the arrangements for both M.L. and B.L. guns are considered, since both are treated in the same manner in the batteries now in course of construction. The word barbette is also taken to include the hydro-pneumatic mountings.

Influences forming the New Designs.—The leading influences forming the designs of the batteries now being constructed are, first, the great cost of the new guns, which renders it necessary to get as much work as possible out of each weapon, and secondly, the great power of the projectiles of the attack against vertical surfaces. This renders protection by iron extremely costly, and has led to the effort to obtain the necessary security by other means. These means have been found in the separation of the guns by long intervals; in constructing the batteries with gentle slopes, so as to deflect projectiles striking them; in concealing the guns and batteries from view as far as possible; and sometimes in using disappearing mountings.

The necessity for moderation in the numbers of guns will be appreciated from the following prices:—A 6-inch B.L. gun of 5 tons, on an H.P. mounting, with 200 rounds of ammunition, costs about £3,500; the same as a 10-inch R.M.L. gun of 18 tons, on a barbette mounting, with its ammunition. A 9·2-inch B.L. gun of 22 tons, similarly provided, costs about £10,000, and a 10-inch gun of 32 tons, £15,000.

But the mounting of guns with large arcs of fire is defensible on other grounds besides economy. It ensures the heaviest possible fire being brought to bear on an attacking squadron at the earliest possible moment. Offence is the best defence; and this will probably prevent the enemy from ever coming to try conclusions with any reserve guns or second lines. The practice is also in accord with modern battle tactics, which forbid keeping guns in reserve on the ground that a gun not in action is useless, and it does not lose in efficiency by firing.

Therefore emplacements should always be constructed so that there may be no obstacle to the gun being fired over the largest arc that can possibly be required of it. And it should be remembered that over water this arc may be much more than can be actually seen from the gun owing to the use that can be made of position finders.

The normal intervals between the guns of a battery may be taken at from 150 to 200 feet. There is nothing magical about these numbers, which have been arrived at simply from reasons of convenience, and if the site requires it, which is sometimes the case, other distances can be adopted. These long distances render it necessary for the enemy to fire at individual guns if he is to do any harm except by chance. They are also very convenient in designing the interiors of the batteries; they render easier the solution of the problems of constructing efficient traverses and secure magazines and casemates, and of providing a good ammunition service and sufficient parapet for rifle and machine gun fire. It was at one time almost laid down as a law that guns should always be "scattered," by which appeared to be meant that they should not be in batteries, but should be placed individually in order to bring a cross fire to bear on attacking ships. It does no doubt at times happen that guns should be isolated, but this is in order to place them in the situations best situated to develop the full effect of their fire, otherwise there is no advantage but the reverse in doing this. Grouping guns into batteries simplifies construction, command, guarding, and supplying, and also the silencing of one gun does not silence a section of the defence. This is the practice actually followed in designs at the present time; sometimes the guns are placed individually, sometimes they are collected into small batteries. It all depends on the ground.

The formation of batteries with long exterior slopes running down to a sunk iron fence defended by fire from the parapet is common to them and to land works, and is adopted for the same reasons in both, namely, to gain increased power of resistance to projectiles, with lessened visibility. The slope should be, if possible, 1 in 7 or 1 in 8, but it has to be made steeper sometimes on account of the nature of the ground. In this case the flat slope at the top should be gradually rounded off into the steeper slope below in a way that will leave no sharp intersection. When a work approaches completion it will often be found that there are unnecessary hollows and steep slopes that can be filled up without interfering with the fire from the parapet. This should always be done, as it will strengthen the work and reduce the depth of the shadows.

The parapets for rifle fire for the defence of the ditch, and for the general protection of the work, are usually formed on the traverses, or at any rate between the guns at a higher level than the crest of the emplacements. The latter are not convenient places for infantry, and by the adoption of this arrangement the superior slope at those important points can be made flatter and stronger than elsewhere. The upper surface of the slopes exposed to fire should be formed of sand to a depth of from 3 to 5 feet, even if it be necessary to go to some expense to get it, on account of its power of deflecting projectiles. Clay should never be used; even stone is better.

This surface will give some trouble in arranging for concealment,

as plants will not grow upon it. A little loam or a thin coating of turf may be a necessity.

Concealment.—Anything that makes it more difficult to aim at a battery will reduce the number of projectiles striking it, and thus increase its endurance. For this purpose care should be taken to have no distinctly marked objects to lay on. Making the slopes of the earthworks as gentle as possible, which is done for the sake of strength, is usually a help in this direction, but these long sloping surfaces are invisible in some places, and very visible in others, according to the surroundings. They must, when requisite, be disguised by irregularities of colour and form. The colour and surface of a battery should harmonize with the surrounding country, and there should be no well-defined sky-line. These are things that cannot be settled in the drawing office. There, all that can be done is to avoid obvious mistakes, to have no sharp angles which cannot be rounded, or deep shadows that cannot be reduced. A sharp projection a few inches high will show literally for miles against the sky, and a steep slope when the sun is low casts a dark shadow that no artifice will disguise. Nothing is so clearly visible as the salient of a bastion. Therefore all intersections of slopes should be well rounded to a long radius, and all projections, such as traverses, should have sides at a flat slope. Projectiles will be assisted in penetrating if the surface rises above the lines of fire at maximum depression on each bearing, or is much hollowed out, but within these limits the surface can be roughened.

It will be seen from this that the finish to a battery can only be given by the local engineer, who must not consider his work complete if he has merely copied a plan.

The concrete of the gun parapets will be found difficult to disguise; it should be tarred or painted. Mixing ashes with it has been tried, but found useless. Perhaps if made with a dark stone the surface cement might be scrubbed off and the colour thus rendered visible.

The final touches must be given on the spot; it is a kind of scene-painting on a large scale. When a battery approaches completion, the engineer in charge should take a boat and slowly cruise round it to study its points, and this at different times of the day, as the shadows alter with the sun. A little cutting here, or filling there, a rounding of slopes, or planting a few bushes may make all the difference. Every battery must be treated individually.

A few examples will make this clear. Thus some batteries built in 1879 were pretty good in form, but had their slopes covered with grass, while all around them was arid sand and rock; consequently, when a ship approached the harbour, the passengers would delightedly call out, "Oh, there are the batteries." On the other hand there are some old batteries at Gibraltar which have in the course of time become so perfectly assimilated to the surrounding ground, that it is impossible to distinguish them, even when their position is accurately known from other land marks.

In the Isle of Wight there is one battery which, on certain bearings, when it is projected against the hill behind, is quite invisible, and can only be localized by the black wooden fencing round it. Black wooden fencing is very visible; wire would be better. An adjacent battery, similar in form, always shows up with a hard and angular sky line.

The 100-ton guns at Malta have been rendered very inconspicuous by being painted a light grey, which harmonises with the stone fences about them.

A battery at Aden is carved out of the back of a natural sand hill, which is undisturbed in front. One would think that nothing could be better, but unfortunately there is a hill of black rock about 100 yards in rear, against which the crest of the battery is sharply defined.

Speaking generally, the exterior slopes of a battery should be left rough and untrimmed. They should not be turfed, but sown with the local grass, weeds, and bushes. Euonymus, tamarisk, and broom are useful shrubs to plant. They should never be mown unless to harmonize in appearance with meadow land surrounding them. Sheep may be allowed to graze on the slopes.

The sky line can be broken by intentional irregularities, and if it has not a background, one can be given it by planting bushes somewhere in rear of the crest. Trees will seldom be suitable; they grow slowly, they will be too tall eventually, and they can burst shells striking them, and can give off splinters.

Organization of Rampart.—On either side of an emplacement it is usually desirable to revet a few yards of the parapet in order to form places for cartridge recesses, for range dials, for the exits of ammunition lifts, and sometimes for the entrances to the shelters for men or to the cartridge stores. This revetment should be kept as low as possible, and these positions laid out so as to be sheltered from enfilade fire. Where this is impracticable, or where large arcs of fire are required, the guns must be put in all-round emplacements.

These should be avoided where possible, as they would cause inconvenience to the artillery in moving and mounting guns and repairing carriages, especially under fire. When used, the access would be by galleries entering either at the rear or at the sides. These would contain the recesses, and would form places for storing side-arms. The lifts or serving hatches might issue in the loading recesses at the back. A compromise between open and closed emplacements is to have an open passage of approach instead of a closed one. This will satisfy the artillery, but will not be very secure.

On either side of the emplacement would usually be a traverse. This will not occupy the whole space between the guns, but the centre would be formed into a parapet for rifles and machine guns.

Along the rear of a barbette battery might run a sunken way about 7 feet below the level of the floor of the emplacements, so as to give additional security to the communications between one part of the battery and another, and also to afford access to the ammunition stores.

Position of Ammunition Stores.—These may be either behind the guns or between them. With isolated guns the former is the usual position (see *Plate* XLII.). A long arched chamber is formed clear of the foundations of the racer, and is divided up for shell and cartridges. From it passages lead to the lifts which issue on either flank of the gun emplacement. This arrangement is suited for heavy guns; for the smaller ones it is somewhat too extensive, and it is better to have the stores on one side only. These may open on an area, and have the projectiles hoisted by a crane, the cartridges being carried up steps by hand. If a battery be exposed to enfilade fire, it may also be desirable to keep the ammunition service on the secure flank, and then the stores might go under the traverse.

In a battery with two or more guns it is economical in construction and convenient in use to build the ammunition stores between the guns. In this case the service would be by a gallery leading to the flanks of the emplacements. If the distance between the guns be short, this gallery must end in lifts; but it is preferable, if the dimensions of the battery admit of it, to ramp it up at a slope not steeper than 1 in 7, so that the gallery floor ends at a level three feet below the floor of the emplacement. A hatch at this height is convenient for passing out cartridges, while shell can be wheeled up to it and then hoisted by tackle, either attached to an overhead bolt or to a traveller running on a short length of rail. This avoids the complication of a lift. The stores should have an entrance by a gallery from the interior of the battery, and this will serve for ammunition in case the other arrangements are put out of order.

When the flank guns of a battery are of small calibre, they can have their ammunition kept in the central store, and be provided with recesses for immediate use.

The arrangements for the supply and storage of ammunition are among the most important and the most variable in a coast battery. Every attention should be given to making the supply easy, rapid, and secure, and every case must be considered on its merits. There can be no cut-and-dried method of dealing with it.

Gorge of a Coast Battery.—The gorge of a coast battery may be made on the same principles as that of a land fort, though, as the garrisons are usually smaller, and the amount of casemated cover required is therefore less, and as coast batteries are seldom liable to a more serious attack on the gorge than an open assault, the details are usually much simpler.

Perhaps the best form of gorge enclosure is a gallery from 6 to 10 feet wide, counter-arched when necessary, loopholed on the outer side, and on the inner or seaward side solidly covered up so as to be safe from projectiles passing over the front parapet.

This not only gives security to the defence of the gorge, but also provides a bombproof for the gun detachments.

It is a form, too, that can be easily executed in a temporary manner with timber.

In a small coast battery for three or four guns, the accommodation necessary for the garrison may be provided by a gorge built in this way, with the addition of a small barrack for the permanent occupation of six or eight men, who would look after the battery in peace time.

Coast batteries are often closed in rear by a simple wall or palisade, and so much, at least, should always be provided, or the battery might be assaulted with success by a few boats' crews landed near.

A wall is, of course, liable to injury from chance shots, but it is not likely to be so much damaged as to be incapable of affording material aid to the defence.

New Batteries.—The drawings and descriptions of a few modern batteries will illustrate the nature of the works which result from the combination of the details just described. These have been designed for actual sites, and are thus illustrations, not types, of

works. It must not be expected, though, that these particular forms will be found really in existence.

The simplest and strongest was designed for Frenchman's Point, near Tynemouth (see *Plate* XL.). Having a cliff in front, partly quarried, partly natural, no front ditch or other defence is required. The parapet is of the sloping type, and dies out on the ground. The armament is two 9·2-inch B.L., and two 6-inch B.L., all on H.P. mountings. The guns are placed 200 feet apart, and are 88 feet above the sea. From its position in an indentation in the general line of the coast, the battery cannot be enfiladed from the sea or taken in reverse; consequently the guns are all placed in emplacements open to the rear. Any shot missing them will pass by and do no harm.

The battery has but small relief above the ground, and the changes of height are slight and the slopes flat, so that it may be expected to harmonize well with the surrounding flat country.

It is proposed to plant shrubs along the gorge parapet, so as to break up the outline.

The ammunition service is from a central magazine for shell and cartridges, to recesses near the guns, from which the charges are taken for use. Casemate accommodation is provided for the garrison, perhaps rather in excess of the requirements, for a naval attack cannot last for long, and there is no need for the men to live under cover. The interior of the battery is sunk so that the communications will be very safe. The gorge is defended by a parapet of the Twydale type.

Another battery was designed for Tombeau Point, Mauritius (see *Plate* XLI.). The guns are old ones, two 10-inch R.M.L., and two 64-pounder R.M.L. The ground it stands on is only nine feet above the sea level, but the use of barbette mountings at such a small height is justified by the fact that a reef off the coast prevents ships coming within machine-gun range. The slope of the parapet is prolonged below the ground level, as in the case of Twydale redoubt, the ditch containing an iron fence, and being protected by fire from the parapet. The guns are 200 feet apart. The ammunition stores are in the centre as before, and the immediate service to the guns is by means of recesses, the charges being carried round by the rear of the emplacements. In a similar case the centre guns might be served directly from the stores by means of lifts, or of ramps, which can be used if not steeper than 1 in 7. The defence of the gorge is concentrated at one angle in order to economise men.

Another battery was designed for an irregular site at Stonecutter Island, Hong Kong (see *Plate* XLII.). The guns are one 10-inch B.L. barbette, and one 6-inch B.L., H.P. In this case the parapet is worked out of the natural hill, and the near defence is provided for by musketry emplacements, arranged to suit the irregularities of the ground. The guns are about 100 feet apart, there not being room for wider spacing. The ammunition supply is entirely underground, lifts being provided at the shoulders of the 10-inch emplacement.

Another battery was designed for Jamaica, where it would be on a low site (see *Plate* XLIII.). As it might be exposed to reverse fire, the emplacements are complete circles. Each gun here has its own ammunition storage and service carried on through bombproof galleries, variously arranged to suit the conditions of each emplacement.

The drawings fairly exemplify the way in which modern requirements have been met. The batteries would be difficult to injure by modern guns, and could be made hard to distinguish, while as large arcs as possible are given to the guns mounted in them.

Where they are all rather behind-hand, according to our present ideas, is in the relative numbers of heavy and light guns. The heavy guns are in excess while the light ones are not numerous enough. It would be preferred to change one 9·2-inch for a 6-inch at Frenchman's Point; and at Tombeau Point the 64-pounder R.M.L. ought to be turned into a 4·7-inch Q.F., or something excelling the the 64-pounder in range and rapidity.

It will be noticed that at Tombeau and at Frenchman's Point the batteries are symmetrical, with the heavy guns in the centre and the light ones on the flanks. This arrangement is by no means universal, as it is unlikely that a battery would be equally exposed to attack on both flanks. The rule to follow is to put the heavy gun in the best place—there will seldom be more than one in a battery—and then to arrange the rest so as to command the water thoroughly in combination with other works. In a battery on the flank of a line of works this would usually lead to the lighter guns being placed on the outer flank of the heavy one. Sometimes the heavy guns will be on the flanks and the lighter ones in the middle. Each case must be judged on its merits; only if it be seen in the design for a battery that one gun is not doing so much work as the rest, then consider if it ought not to be moved.

Howitzer Batteries.—Pending a decision on the nature of the mounting, it is impossible to give an exact description of a suitable form of battery. A few points, however, may be noticed.

There are three peculiarities about heavy R.M.L. howitzers, mounted and used solely as such. They are fired only at angles of elevation probably not less than 25° or 30°; they have a very short recoil horizontally, and they use varying charges of powder.

The form of parapet that suits the first and second conditions is one with a small covered way running round the front of the emplacement, from which the howitzer can be loaded; the mass forming the protection rising above it, so as to cover the howitzer and the detachment.

The supply of cartridges must be met by having a recess or small casemate close by, in which cartridges of various weights can be kept in readiness, so that when called for they can be at once issued.

The laying is done entirely by position-finder, to suit which the howitzers should be arranged in groups of two or three as near together as possible. The minimum interval, allowing for the emplacements to be separated by a traverse, will be found to be not less than 80 feet.

Difficulties are likely to occur in connection with the service of ammunition from the stores to the muzzle of the howitzer. It may be noted that the vertical distance from the racer level to the crest of the parapet is not likely to be less than 12 feet.

Almost all howitzer batteries must be arranged to allow of large arcs of fire being used without danger to the ammunition stores, or to the neighbouring detachments.

8.—BATTERIES FOR THE DEFENCE OF SUBMARINE MINES.

Nature of the Attack.—The attack on submarine mines would be carried out by vessels of small size, such as steam launches and small gunboats, provided with light protection only, if with any at all. Therefore it is not necessary to provide armour-piercing projectiles for use against them.

Possibly, in future, lines of mines may be attacked by ships throwing large masses of explosives from pneumatic guns, but as these would operate from some distance in advance of the mines, they would be dealt with by the guns provided for the general defence.

The Fire of the Defence.—As the attacking vessels will be numerous, and their operations will be carried out at night when there will be many difficulties in the way of correct aim, it is necessary to be able to fire large numbers of projectiles.

This condition may be met in two ways—either by firing shrapnel from medium or heavy guns, or by using Q.F. guns. Preference has been given to the latter for various reasons.

In the first place all the projectiles can be aimed if the object can be seen, whereas a number of the bullets from a shrapnel shell fired at a boat must necessarily be wasted. If blind firing through smoke or mist be necessary, it can be carried out with Q.F. guns equally well as with shrapnel, by traversing the gun between the shots. Again with Q.F. guns the fire can be continuous, whereas with shrapnel there would be intervals. Also in defending a mine field it is usually very necessary to direct one's shots with precision in such directions as will not injure one's friends, either in guard boats or occupying the opposite bank of a channel, and this condition is best fulfilled when the shots are all aimed, as from a Q.F. gun. Moreover, the Q.F. guns being small are more easily concealed from view, and not being very costly it is possible to devote some of them entirely to mine defence, not allowing them to take part in the preliminary fighting at all.

The Guns Used.—The guns used for mine defence are the 3 and 6-pr. Q.F., and 4·7-inch Q.F., according to the range required; the two smaller for about 1,000 to 1,500 yards, the larger for longer ranges or more important sites.

The 3-pr. would be worked on a travelling carriage, which is heavy enough not to be moved by its recoil. The 6-pr. would be on an "elastic frame" mounting, or perhaps on a "balance pillar." The 4·7-inch should always be on a "balance pillar," but a central pivot-mounting may in some cases be used. For descriptions of those mountings see Chapter II., Section 1.

Batteries for Mine Defence Guns.—The chief point to aim at in arranging the batteries for the defence of mine fields is so to conceal or shelter the guns, that it may be impossible for the enemy to put them out of action by fire until he is close upon the mines.

This may be done by putting the guns in hollows of the ground or behind projecting spurs, or by forming traverses on the exposed side, disguising the work by planting.

It will seldom be possible to place the guns in regularly formed batteries, as this would betray their position. Sometimes when the guns have to be placed at the foot of a steep slope, or are necessarily in such a position that other guns may have to fire over them, they

may be mounted in little casemates, which being so small are not difficult to conceal. These are described further on.

The balance pillar is a very suitable mounting for this sort of work, as the guns can be kept quite hidden during the daytime. At night when they may be brought into action, it will be so difficult to distinguish them that exposure does not much matter.

As a rule the guns will be so placed as not to command the water at all much outside the front line of mines, but this will not always be the case with the 4·7-inch Q.F. gun, both because of its power rendering one reluctant not to bring it into action as soon as possible, and also because it will usually be employed where there is a wide stretch of water to be commanded, and where concealment from the outside will, consequently, be difficult.

Mine defence guns should be placed near both flanks of the line of mines to be defended, preferably a little in rear of it, so that the projectiles from each battery may go clear away from the defenders on the opposite bank.

They should be near the water level, so that boats may not be able to slip past under them, and in order to get the full advantage of the flat trajectories in blind firing at night.

They will usually have to be near the shore, so as to get the utmost accuracy, and so as to be in the most advantageous place for seeing boats coming in.

They would, of course, have to be associated with electric lights, which must not be placed too near them, both in order not to dazzle the gunners, and not to draw fire on the batteries. The lights will be movable, and will be under the orders of the officer commanding the mine defence guns. His post must, therefore, be fixed, and there must be means of communication between him, his guns, and the lights. Probably he would be at his guns and would direct the light from there by electrical gear, see Section 11.

For convenience of command and direction, it is advisable that the guns should always fire from the same points. The movable 3-pounder Q.F. guns should, therefore, have emplacements prepared for them, into which they should be run when preparations are being made against an attack on the mines. Alternative emplacements may be prepared both for these guns and for those on elastic frame mountings, but it must not be imagined that it will be practically possible to move the guns from one to another during an action. The place chosen must be kept to.

Emplacements.—The nature of the emplacements for the various mountings are all described in Chapter II., Section 1, except the casemate for a 6-pounder Q.F.

This is a small chamber with concrete walls and floor, and a roof made of steel decking, or of rails, with concrete over.

The dimensions are—8 feet square internally, with a passage way 4 feet wide in rear. It should be at least 6 feet high at the pivot of the gun, and may run up to about 7 feet 9 inches in rear. The decking is curved down to form an embrasure about 5 feet 3 inches wide, and 2 feet high, which admits of an arc of fire of 90°.

The gun is mounted on an elastic frame, which is bolted to the 3-inch planks on the floor, arranged in the usual way. The front ends of these planks are carried under the wall of the casemate into a recess, where their upper surfaces bear against a rail, built into the wall.

With the balance pillar mounting it may occasionally be found convenient to arrange for the gun to fire to seaward from its high position and over the line of mines from its low position, the parapet being made in two levels accordingly. The advantages of this arrangement are that the gun can either be used to seaward or be concealed from that direction as wished, and that when in action over the mine-field the high part of the parapet acts as a traverse. Its being visible over the mine-field does not matter so long as it cannot be seen from the sea beyond. Where this condition cannot be fulfilled this arrangement is unsuitable for adoption.

9.—SUBSIDIARY BUILDINGS IN BATTERIES.

The requirements of the artillery in the matter of storage for the side arms and small stores of guns are so very varied that it is practically impossible to lay down definite rules as to how they should be met. In preparing the design for any particular battery, as soon as the armament is decided on, the requirements will be at least approximately known, and the artillery should be consulted as to their wishes in this respect. A few general observations on the subject will, however, be of service.

The artillery stores for the service of guns permanently mounted are four in number:—

1. General artillery store.
2. Artillery store for small stores.
3. Store for side arms and tackle.
4. A smith's shop or a workshop.

General Artillery Store.—1. The general artillery store is intended to take reserve and unserviceable stores which are not immediately required for the service of the guns. No particular size or position in a work can be assigned to it, but it is a necessity in any large fort or battery. It should be fitted with hooks for tackle, racks for side arms, bays or racks for handspikes, and benches and shelves for small stores. Any arrangement may be adopted that is convenient for storage, as the articles are not appropriated to particular guns.

Artillery Store for Small Stores.—2. Artillery stores for small stores take such articles as sights, elevating arcs, breech-pieces of B.L. guns, and other removable fittings; also preventer ropes (for such guns as require them), an arrangement adopted to suit the drill. They should be near the guns, so that there may be no delay in getting out the fittings for the latter, and it is desirable that they should be quite separate from the side arm and tackle store, so that the metal work kept in them may be clean and free from dust.

For R.M.L. guns they should be provided with a continuous bench with cupboards, and two shelves on the wall above. If there be sufficient space, the bench and shelves should be divided off by painted lines into compartments, each devoted to one gun, whose number and calibre should be marked above it. The compartments may be about two or three feet long, according to circumstances.

The remaining fittings are hooks to take tube boxes, one per gun hung by a strap; hooks to take prickers; bench for tools and implements; and a cleaning bench, with a vice and a shelf above; also brackets for preventer ropes, one per gun. No such store should be fitted for more than eight guns.

B.L. guns require a bench, a shelf, and a row of pegs. The bench should be 2 feet 6 inches wide and 3 feet above the floor; the space underneath being closed in to form a cupboard. The shelf should be one foot wide and two feet above the bench. The pegs six inches apart below it.

In addition for every battery of 10 guns or less there should be a length of shelving equal to that for one gun where a vice can be fixed and small repairs executed. A small cupboard is required under this.

In addition for each nature of B.L. gun in a battery, there should be a space equal to that for one gun where spare breech screws can be stored on the floor, with a cupboard over for oil rag, waste, etc.

A 6-inch B.L. gun requires 3 feet 6 inches run of shelving; a 9·2-inch requires 5 feet run, and a 10-inch gun requires 5 feet run.

Heavy guns in casemates require no small store accommodation, because their fittings are left permanently with them.

Side-arm and Tackle Store.—3. The stores for side-arms and tackle are intended to hold the sponges, rammers, handspikes, tackle, and other appliances of that nature intended for working the guns.

They must be near the guns they are intended to serve, in order that there may be no delay in getting ready for action.

The fittings they require are a rack for side-arms, about 14 feet long, 5 feet wide, and 6 feet high, with cross bars at every 2 feet in height; bays for handspikes, one per gun, each bay about 1 foot 6 inches wide, and formed by a wooden projection from the wall, 4 feet above the floor; hooks for brackets, one per gun; tackle brackets, two per gun, in two rows, 3 feet and 6 feet above the floor, respectively, each bracket of round, or half-round iron, 12 inches long; and some shelves for brushes.

Care should be taken that there is an easy way by which to remove the long side-arms from the store.

No side-arm store should serve more than eight guns.

No side-arm store is required for guns mounted in casemates, as the side-arms are kept with the guns; except that there must be some convenient place for keeping the wadhooks, shell extractors, and brushes, which are allowed at the rate of one for three guns.

Side-arms for single guns are often kept on hooks on a wall, with a pent roof over them, if necessary, to protect them from the weather.

They may also be conveniently kept on bars, fixed across a passage at a height of from 6 feet 6 inches to 7 feet from the ground, so that the heads of the side-arms may be clear of the heads of persons passing under, while at the same time they may not be too high for convenience in taking them down.

Some assistance in determining the amount of artillery store accommodation may be obtained by consulting the *Manual of Siege and Garrison Artillery Exercises.*

Machine Shed.—In addition to these stores, at each station, or large artillery district, will be required a machine shed for keeping triangle gyns, sets of heavy tackle, and such articles, used in mounting or transporting garrison guns.

Smith's Shop and Workshop.—4. The smith's shop is intended to contain a forge, and other articles required for making small repairs to

the ordnance and mountings. It should therefore be within a convenient distance of the guns, and should be carefully protected from projectiles, since it may be of the utmost importance to repair damages during an action. The building should be about 20 feet by 16 feet, and 10 feet 6 inches high. It should contain a forge, anvil, and grindstone, a bench with a vice, and a set of fitting tools.

In places of importance, where heavy guns are mounted, a workshop will be added. It will be about 12 feet by 16 feet, and 10 feet 6 inches high, and will contain a screw cutting lathe with 6-inch centres, a hand-drilling machine, and a set of Whitworth stocks and dies. Shelving should be provided on the walls where convenient.

Nomenclature of Stores.—For the proper naming of these and other stores see the "Regulations for the R.E. Department on Lettering Emplacements and Accessories in Works of Defence."

Lamp Room.—A little room in which the lamp man can keep and clean his magazine lamps is necessary where there are many in use.

Bombproof Cover.—Some bombproof cover should be provided in every battery that is likely to be at all closely engaged. It will serve various purposes, among others that of a shelter for the wounded, and for men not actually engaged at the guns. A corner might be partitioned off for the telephone, by which every battery should be connected with the officer commanding, or with the position finder station. A bench under cover from the weather, which might also be in the bombproof, would be a great convenience for the artillery when at practice. The men have often to stand about for hours waiting for the range to clear, or in bad weather.

Tank.—A tank should be provided in a secure situation near every battery. Water is required both for the guns and the men.

Shell Filling Rooms.—The question of the necessary requirements of shell and cartridge-filling rooms has for some years been a subject of discussion, but is now settled by an alteration in the Magazine Regulations.

It is intended in future to issue all cartridges made up and packed in zinc cylinders ready for use, and to fill all shell at the station before sending them to the batteries. Ammunition for practice will be taken from that in store. Cartridges will be taken to a central R.A. laboratory for examination. Shells will be examined at the battery, but any found defective must be taken to the shell-filling room to be emptied and re-filled. A convenient shell-filling room must therefore be provided for each group of batteries, so as to avoid transporting heavy shell to long distances. These rooms will also serve for filling small shells for battery practice. These new regulations render unnecessary the construction of a large number of shell and cartridge-filling rooms, which were essential under the old ones. For details of a shell-filling room, such as is now required, see Chapter III., Section 7.

10.—POSITION FINDING.

Position Finder.—The following is a short account of the most important adjunct to coast batteries yet invented, and one which without any exaggeration multiplies several times the value of any gun to which it is applied. That is the Position Finder, an instrument by which a gun can be directed with the greatest precision on to the spot at which it should be fired in order to strike a vessel, even if the latter be in rapid motion, and which provides for its being discharged at the right moment. Its invention is due to Major Watkin, R.A., who has worked at it for many years, and who has now brought it in its main features to absolute perfection. It passed its final trials with great success in 1887, at Plymouth, where the defences of one side of the harbour had been fitted with it as for service, and it is now being generally applied to all our coast defences.

The details of the instruments are kept secret, but the mode of application and practical working can be described.

There are two natures of Position Finder: the "depression" and the "horizontal."

With the former a range to the water line of a floating object is obtained by the measurement of the angle of depression to it from the instrument; the base of the triangle to be solved being the height of the position finder above the water. The direction of the object is observed by something of the nature of a plane table.

In the "horizontal" system there are two instruments, and the base is the distance between them. The "receiving" instrument is similar in pattern to the "depression" one, and if there is any height for it, may with advantage actually be a "depression" instrument. The "transmitting" instrument at the distant end of the base consists of little besides a telescope. In certain situations it is advisable to have a depression instrument at the transmitting end as well as the other; and sometimes a single "receiving" may be combined with two "transmitting," having bases in different directions

So far the matter is comparatively simple. *The* difficulty in designing a position finder lies in the conversion of this range and direction, as found at the observing station, *instantaneously* into the corresponding figures for the gun, which may be at some distance off, and the equally instantaneous communication of these figures to the gun detachment for use. Any delay is fatal to the chance of hitting a moving object.

In the depression position finder a telescope is pivoted vertically and horizontally, so that it can be directed on to the water anywhere within the field of view. By a perfectly simple but extremely ingenious device, the act of directing this telescope on to the water-line of any floating object indicates on a couple of dials, placed in the battery, the range and training to be given to the gun with which it is connected, in order that its projectile may strike that same object. A similar result is obtained with the "receiving" instrument of the horizontal system, at which the two observations are combined, if both instruments are directed on the same part of the ship. Thus by the mere act of the observer in watching a ship the gun can be kept directed upon it.

Even this, however, is not sufficient in the case of a moving object, to strike which the gun must be fired in advance of it. To meet this difficulty a pencil attached to the instrument is made to plot the course of the vessel to be attacked. A prediction can consequently be made of the spot she will occupy in, say, half a minute. The gun is laid to strike this spot, and on the ship coming into view in the telescope it is fired by electricity by the observer. This may sound complicated, but the actual working is simple, and was done by non-commissioned officers at Plymouth with eminent success. It was a very pretty sight to watch the shot from a group of four guns fired together curving down towards the target, and striking the water close to it.

At Plymouth also was shown the successful directing and firing of guns in the Breakwater Fort from instruments on the main land more than a mile away. There are disadvantages attaching to the long interval between the gun and the observer, and they should not be unnecessarily introduced, but this trial has demonstrated that they are by no means insuperable.

The position finding instrument, as tried at Plymouth, stands on a table 4 feet long and 2 feet 3 inches wide; about the size of a large drawing board. The telescope is pivoted near the centre of the inner side. It is placed in a small building or "cell" partly sunk in the ground, and having a long low opening in front, of such a size as to permit of the telescope covering the whole of the water which could be struck by projectiles from the gun it is serving. The roof is covered with earth so as to assimilate it as much as possible to the rest of the hill side. The heights of the stations above the sea were 250 feet for Bovisand Battery, which was close by, and 350 feet for the distant Breakwater Fort.

Each instrument is constructed to give the range from a single point, and is therefore useful only to a single gun, unless two or more guns are so close together that their shot will strike a ship when fired parallel, and when they fire over the same water.

This was the case at Bovisand Battery, where the guns were grouped in fours.

At the Breakwater the guns are worked singly, having widely divergent arcs. In modern batteries, as a rule, single guns will form "groups."

The instruments tried at Plymouth were constructed to read to a maximum range of about 5,000 yards. The present service patterns are for ranges of 7,000, 12,000, and 14,000 yards from the instrument, the arc of fire of the gun falling within this. The smaller service pattern is sufficient for the old M.L. guns as at present mounted. The "cell" to accommodate it is 9 feet long by 8 feet 6 inches wide in internal dimensions. Those for the others are a little larger. This admits of the employment of two observers, which is always convenient, and sometimes necessary. The top of the roof may be taken as being 3 feet above the axis of the telescope of the instrument. The maximum arc of view is 180°. As much light as possible should be admitted. The cells should, if possible, be about 50 feet apart, but circumstances may compel them to be nearer, even touching.

In laying out a depression system the instruments should be as high as possible, up to, say, 800 feet, which is enough for anything. Results good enough for short ranges, say to 2,000 yards, can be got from as low as 25 feet, but the instruments then must be near the guns. In a horizontal system the effective base, that is, the perpendicular distance from one end of the base to the opposite side of the triangle, for a 10,000 yards range should not fall below 1,200 yards. It is desirable not to place the receiving instruments more than about 500 yards from their groups of guns. Several "cells" placed together are called a "station."

These data will give a general idea of the information necessary

for laying out the "cells." For more detail, reference must be made to official publications.

In a battery the fittings at present in use for position finding are; the electric batteries, which may be almost anywhere handy; the firing plug, about 6 inches square, which takes the end of the flexible insulated wires leading to the electric tube for firing the gun, and which must be near the gun; and the dials and firing key. The latter is best placed in a recess 2 feet 3 inches long by 1 foot 4 inches wide by 8 inches deep, and must be so situated that a man can read the dials and give the word of command to the gun at the same time. An arrangement now under trial may alter this.

There will be a good deal of work done in connection with position finders in the immediate future, and a warning may be given that, in laying out position finder stations, the great difficulty lies in the uncompromising nature of its requirements as to its field of view, and in the narrow choice of positions that results from it. The arc of view of the instrument must cover the arc of fire of the gun up to its extreme range, and there is no give and take possible. It is well to draw this out on paper before hazarding any but the vaguest speculations as to the sites of the position finders.

For every section of the defences a place should be provided for the commanding officer, from which he can watch the action, give directions to the observers, and communicate with the battery by telephone. This might be a building of a pattern similar to those for observing, with additional accommodation for telephonists and orderlies.

The communication between the position finders and the battery is electric. A cable of seven wires is required for each instrument to work the dials, the firing, and the signals in connection with the latter. Telephone wires are additional. Two instrument wires and two telephone wires are at present required between the ends of each horizontal base.

On land the cable will be laid in a trench at least three feet deep; more in exposed situations. Special attention must be given to bringing the cables into the battery by a secure route. At Bovisand they go down the magazine passage and are brought up the lifts.

In order to give the gun the range signalled on the dial, an arc and pointer are attached to the gun near the breech, the arc being graduated in yards, calculated specially for the height of that particular gun above mean tide. Various forms of arc and pointer are used, and in some cases a clinometer attached to the trunnions, but the principle of the graduation is the same, namely, that it is given in yards for the particular gun.

The training is given by means of a training arc let into the floor, and graduated in degrees and quarter degrees, and by a pointer attached to the platform. The arcs are fixed by screws to small blocks set in the concrete or stone floor. They must be laid to the radius stamped upon them. The Royal Engineers have to fix these arcs, and they give a good deal of trouble. They must be laid with all attainable accuracy, but the old platforms do not fit very well, and have a way of getting askew on the racers, so that there is a different reading according as you traverse up to a line from one side or the other. The only thing to be done is to take an average of several readings. The new mountings are better in this respect.

The zero line of the training arcs in all new works is to be true north; that is, any gun laid true north should have its pointer at zero, and any two guns whose pointers may be at the same degree are parallel in plan. It will be neccessary in every battery to lay down a meridian line, and to take bearings to prominent distant objects which are within the arcs of training of the guns. The number of the graduation at some points in each of the training arcs can thus be determined and the arcs fixed accordingly.

An Inspector-General of Fortifications' Circular, No 516, 2nd May, 1887, has been issued on this subject, giving all necessary information.

It should be remembered that the "cells" containing the instruments depend for safety on concealment. Local surroundings must therefore be carefully studied.

This short description of the position finder system will enable its chief features to be understood, as they affect the Engineers.

Those who have to carry out the practical application of it in any of our fortresses will find a great deal of information in the report on the Bovisand experiments. It is very confidential, but will be found at all stations in charge of the Commanding Royal Engineer.

Also a small pamphlet, called "Notes on the Application of Position Finders to Coast Batteries," has been issued, in which it is hoped that all information necessary for Engineers in the laying out and construction of position finder systems may be found.

Depression Range Finder.—The depression range finders have been issued in large numbers, and will continue to be supplied to batteries when there is a height of even 25 feet in their immediate neighbourhood to take the place of the position finder if that instrument should happen to get out of order.

In choosing sites for it, alternative positions should be selected on both flanks of a battery, so as to be able to avoid the smoke. A fair field of view is of course necessary, and as much security as is possible. The emplacement for it consists of a pit 6 feet in diameter, in which is built a brick or concrete pillar, 4 feet 4 inches high, 1 foot across, and projecting 2 feet from the side of the pit. On the top of this pillar is fixed a small brass stand to take the levelling screws of the instrument, which is supplied by the artillery. The ranges will be transmitted to the gun electrically.

Datum Points.—One or more "datum points" are required for this as well as for the position finder, by which the instrument can be adjusted for height above water level. This may be the end of a pier, a pile, a rock, or any similar object always surrounded by water. The best distance is about a mile off, when it gives a good long base but still is easily seen. Where there is not much tide, one datum point visible from each instrument is sufficient to check it by, but if there is a considerable rise and fall, each instrument should see two, one on either flank, as it will be necessary to set it occasionally during an action.

11.—MISCELLANEOUS.

Power for Working Heavy Guns.

Power for Working Heavy Guns.—As this book aims at being practically useful, it does not seem worth while including much about working heavy guns by power, but a few remarks may, nevertheless, be of interest.

Experiments have been in progress for several years, with a view to obtaining a satisfactory means of applying power to the working of heavy guns in land works, but, up to the present, without any decided success.

A system of hydraulic working, applied to two 38-ton R.M.L. guns at No Man's Land Fort, was tried in 1876, but the Committee under whom the experiment was carried out reported against its adoption.

A method of working a 38-ton gun by steam power was tried at Shoeburyness in 1881. It was not altogether satisfactory, but had the great advantage that, with its aid, three men could work the gun.

A development of this experiment was to be carried out at Portland Breakwater Fort, where two 12·5-inch 38-ton R.M.L. guns were to be fitted with complete steam power; two with partial steam power for sponging, ramming home, and traversing; and two with revolving bollards for assistance in hand working. A thorough trial of this kind was thought likely to give results which might solve the question of the employment of power for M.L. guns, and give useful information for its adaptation to B.L. Guns, but owing to various changes the trials have never come off.

In order to serve the cartridges to the 12-inch B.L. guns mounted in the Spithead forts, it has been necessary to apply steam power to some lifts, hydraulic to others, the rest of the service of the guns being done by manual labour. It is now proposed to try compressed air or hydraulics for working the guns themselves.

The 80-ton guns in Dover Turret are worked by steam power.

The 100-ton R.M.L. guns at Malta and Gibraltar are worked by hydraulics.

With regard to the advantage to be gained by the use of power, it should be noted that, as far as speed of working goes, a well trained detachment can work and fire a 38-ton gun faster by hand than with the experimental steam gear. The partial use of steam gear, applied in the manner proposed to be tested at Portland, gave the most rapid rate of firing. Unless some great advantages are to be gained in rapidity of fire, security, and economy of men, unless hand power can be resorted to on an emergency, and unless it can be ensured that the machinery shall always be kept in thorough working order, I think that the introduction of steam power for guns that do not absolutely require it would be a questionable benefit.

The navy commenced with the use of steam power, but soon abandoned it for an hydraulic system, by means of which all the heavy R.M.L. guns of the large turret ships are worked. They have now taken up what is known as the "Collingwood" mounting, described in Chapter IV., Section 4, and which also is worked by hydraulics. This system seems well adapted for use on land when it is required to mount B.L. guns of such a weight as to require power in any case. The armoured wall used on board ship can be replaced by earth and concrete on land, and very nearly the full protection of a turret can be obtained without the turret itself. This system of loading is being used by the Italians and Russians for guns of over 100 tons weight.

Of the various means of using power for working guns, steam seems to be the most certain in its action, but it has the disadvantage that the gearing required to transmit the motion is difficult to arrange conveniently, and it is very noisy. It also seems difficult to get precision of movement with steam gear, so as to be able to stop a gun absolutely at a certain bearing or elevation. To do this is essential with position finding. Formerly it did not matter, as the gun could be fired on the move.

Hydraulics give precision of movement, are quiet and compact. They are said to be somewhat uncertain in their readiness for use, but I should think that this objection was rather out of date. The waste water on the gun floor is unpleasant.

Compressed air would seem to be open to the same objections as steam, but the waste air would serve to ventilate a casemate. If an air pipe be injured only a certain reduction of pressure ensues. It might be used without much gearing for driving a small engine in the mounting, and in this way has been tried with considerable success.

Electricity has been tried, but up to the present has not proved sufficiently satisfactory for adoption. It should be quiet and well under control. It is well suited for bringing power from a distance. There is a certain danger from sparking and from a wire being partly cut and heating from the current.

It is very possible that there will be a considerable development in connection with the application of power to heavy guns, as they could then be laid direct from the position finder and kept continuously on the object, being fired when ready. This would increase the rapidity of fire, and would eliminate certain operations with their attendant liability to error. The question is under consideration. There is no special difficulty about it, but the cost of the machinery is likely to be considerable.

Effect of Blast.

Effect of Blast.—The blast from a heavy gun can produce a very considerable effect on surrounding constructions if circumstances happen to be favourable to it, and sometimes they are unintentionally arranged to be so.

Curiously enough, the blow given by the rush of the gases out of the gun does not seem to do much directly. It certainly necessitates a layer of stone or concrete under the muzzle of the gun, which should be at least three feet thick for a 38-ton gun, and may be less for smaller ones, and with a well-finished smooth surface, not rendered; but even here there is an after effect in an upward direction.

What does produce an effect is the partial vacuum, caused by the forward rush of the gases of the charge, and the consequent in-draught of air from all sides to fill it. The doors of recesses and stores are burst open, windows broken, even the walls of light buildings moved, by the attempt of the enclosed air to expand, when the exterior pressure is thus diminished.

That it is expansion from the inside, and not pressure from the exterior, that causes the injury, is shown by the fact that the fastenings all give way outwards.

The iron bars securing the doors of shell recesses, which are $2\frac{1}{4}$ inches wide, and $\frac{1}{2}$ inch thick, have been bent from the effect of firing a 9-inch R.M.L. gun. This is an instance of what the blast may do, and shows that it is necessary to minimize its effects as much as possible. The way to do this may be best illustrated by two examples. In a certain iron-fronted battery there were two embrasures not yet fitted with shields, and therefore forming large openings into the casemates; 9-inch guns were mounted to fire through these embrasures, the rest of the battery being armed with 10-inch guns, firing through proper ports cut in armour. Practice with the latter guns was attended with no inconvenience whatever, but on firing the 9-inch guns out of the large embrasures, the doors of the lifts and other pieces of woodwork in the casemates were wrecked, and the men working the guns felt the shock most unpleasantly.

In this case the air could rush freely out of the large opening to fill the vacuum caused by firing the gun, while with the 10-inch guns mounted behind small ports, the movement of the air in the casemates was checked by having to pass through a restricted aperture. Therefore, one way of preventing injury from blast is to place some screen between the muzzle of the gun and any object that is likely to be injured.

This, however, can only be done with a casemate; a shield without overhead cover is not enough, as was proved by the case of a 9-inch gun behind an open battery shield, the firing of which broke open the door of a shell recess close by, and bent the iron fastening.

This was remedied in the following manner:—the recess was in the side of a long traverse, and through this traverse a passage was cut, opening close to the recess. This allowed air to come through

the passage to fill up the partial vacuum formed in front of the recess when the gun was fired, and thus reduced the difference between the pressures of the air inside and outside the door, so that the latter was capable of resisting it.

The other way of preventing injury from blast is therefore to provide a free passage for air to supply the vacuum caused by the firing in that part of the work where injury is likely to be caused.

Casemates therefore should have small ports but some large openings in rear; doors should never be put in corners at a distance from these openings where there is no free passage of air past them; their fastenings should be strong, for there will always be some tendency for them to burst open.

If it be impossible to arrange the battery properly in this respect, an open grating in a door will sometimes be enough to save it.

Direct Action of Blast.—This may be taken to be in front of the plane of the muzzle only, not in rear. This was proved by firing a 38-ton gun with only six inches protrusion of the muzzle beyond the crest of the parapet, when no effect was produced inside the emplacement. Observation on this point may be made whenever a gun is fired by noting the marks on the parapet.

Safety of Ammunition.

Firing at Cartridges.—In the course of a competition between the Hotchkiss and Nordenfelt machine guns, carried out by the Admiralty in 1880, it was determined to fire at some cartridges of P powder, in order to see whether the 1·42-inch shell of the Hotchkiss would explode them more readily than the 1-inch solid shot of the Nordenfelt, and it was supposed that the shell would have the advantage. But the case proved to be different, for whenever a projectile struck with sufficient velocity it exploded the powder, whether it were a shell or not. The only cartridges which were struck and not exploded were some where the velocity of the bullets had not been sufficient to carry them through the charge, and they were found sticking in the powder. The cartridges fired at were some in zinc cylinders, some in Clarkson cases such as are used on board ship, and some without any cases, and always with the same results.

Further trials have shown that shrapnel bullets will also explode cartridges, and other trials with the Martini-Henry rifle appear to indicate that P_2 and prismatic powder ignite more easily than R.L.G. or L.G.

These experiments, coupled with the fact that war ships of all nations now carry large machine guns of some sort, showed that the chance of the explosion of a cartridge on the gun floor of a fort was much greater than had been previously assumed to be the case, and experiments were consequently carried out to discover the probable results of such an explosion, and how to minimise its effects.

Effect of exploding P and P_2 Powder.—A number of cartridges of P and P_2 powder were fired under different circumstances, and the general results were as follows :—

The explosion of P powder in the open is much more violent than that of P_2 (P powder consists of 1-inch cubes, and P_2 of $1\frac{1}{2}$-inch cubes). Indeed P_2 could hardly be said to explode at all, but to flame rapidly away. Neither would do much harm to the *matériel* of a battery, but would burn the men terribly. Burning pellets were projected to a distance of about 12 yards.

The Communication of an Explosion.—It proved very difficult to ignite a cartridge when in its zinc cylinder by the explosion of another P_2 charge near it; they might be put as close as 6 feet without any other result than that the unexploded cartridge would be knocked down, and the case made hot enough to blister the paint. The present moulded powders are more difficult to ignite than P_2.

This showed that, provided the cartridges in a heavy gun battery are not allowed to get near one another, the explosion of one is not likely to be communicated to the rest; this is a cheering result to have arrived at, for the amount of gunpowder used by the heavy guns is considerable. At Spitbank Fort, for instance, mounting nine 38-ton, and six 7-ton guns, with two charges per gun sent up from below, there would be nearly $1\frac{1}{2}$ tons of powder on the gun floor.

160lbs. P_2, the charge for a 38-ton gun, hung up in the top of a lift and fired, would explode a cartridge in its zinc cylinder standing in the bottom of the lift; but it would not explode it, only heat it and knock it down, if standing 18 inches in front of the lift below.

Q.F. Gun Cartridges.—It has been found by experiment that if a 6-pounder cartridge which is enclosed in a brass case be exploded, it is liable to fire others in contact with it. Smaller cartridges are safe.

Shells.—Common shell struck by a projectile will explode, but placing shell and shot alternately will prevent the explosion from extending.

Woodwork about Lifts to be avoided.—It is found that the great blast of flame from cartridges burnt in the open air sets fire to woodwork that it comes in contact with; the action is so rapid that it

seems probable that a thick coat of whitewash would be enough for safety, but this cannot be counted on, and it is advisable to have as little woodwork about the cartridge lift as possible. Doors are often a necessity, but they can be whitewashed, and are well in view so that any smouldering can be easily distinguished, but the use of battens inside the lifts should be entirely abandoned.

Speaking Tubes.

Speaking tubes are extensively used as a means of inter-communication in coast batteries. They have the advantages of simplicity, of their working being easily understood, and of being capable of transmitting verbal messages; in all which points they are superior to any system of signals, whether electric, pneumatic, or by steel tape; but they have the disadvantages that they can only be used for a limited distance, and that an external noise renders the message difficult to hear. The telephone has not as yet proved itself suitable for use near guns, mainly because this last objection to speaking tubes is much greater in the case of telephones. They are also more costly and liable to injury.

Construction.—The tubes used originally in our works were made of 1-inch iron gas-piping, and this is satisfactory enough for short distances, such as from the top to the bottom of a lift; but when the length exceeds 100 feet, words can with difficulty be distinguished, even when the interior of the tube is clean, and, being iron, it is liable to be clogged with rust.

When a long tube is required, one made of composition of lead and zinc, $1\frac{1}{2}$ inches in diameter, should be used; the increase in size makes a great difference in the ease with which the sound is heard. This is available up to lengths of 200 feet in ordinary cases, and up to 300 feet in favourable instances, where there are few bends in the tube, and when the listener is undisturbed.

Fixing.—The tube may be fixed in any manner that may be convenient, whether in a groove in the wall, or suspended on hooks. It is not necessary to pack it or cover it up, except to protect the composition from blows; and it is desirable to place it so that it can be easily got at and repaired in case of injury.

There should be no right angles in its length, and curves should be as few and gentle as possible.

The slope of the tube should be continuous, so that condensed moisture may not lodge in it.

The ends should be fitted with zinc whistles, with tell-tale pins in them to indicate which whistles has been blown. When the tubes issue in places where they are accessible to everybody, as in a barrack room, the whistle should be removable, and the ends of tubes should be closed by screw plugs, capable of being taken out only by means of a key, like a railway door key. Mouthpieces, whistles, and other fittings, form the subjects of a W.O. contract.

The mouthpieces should be of the same interior diameter as the tubes to which they are fitted.

They should be at a height of 4 feet 9 inches above the floor, and may be inclined upwards, so that they can be easily spoken into. Care should be taken not to place mouthpieces in corners where they cannot easily be got at; nor to put two so near together that they cannot be used simultaneously.

It may be observed that zinc tubes should not be used, as they are found to perish under the action of the lime in mortar; also the wooden whistles soon get broken.

Provision to be made in Coast Works for Submarine Mining Apparatus and for the Electric Light.

Submarine mining apparatus and stores would as a rule be kept separate from forts and coast batteries, so as to run less risk of injury from projectiles, and so as not to be interfered with by the smoke of the guns. A certain amount of accommodation is, however, sometimes required for observing stations, test rooms, and electric light apparatus.

Observing Stations.—When in the vicinity of test rooms and using their firing battery, observing stations are generally made about 6 feet by 4 feet, with an average height of 6 feet 3 inches, sufficient room being left in front of the observer for the depression position finder. To render them as inconspicuous and secure as possible they are generally sunk, with the roof about the ground level, and covered with a 3-inch armour plate.

When at a distance from a test room and employing a separate battery, a small room about 10 feet by 8 feet is required in connection with the observing station. If concealed from the view of the enemy, and not likely to be injured by stray shots, this may be of a lightly built character; otherwise it should be made bombproof.

Test Room.—The test room should be bombproof; its dimensions are 20 feet by 16 feet by at least 6 feet 6 inches high. Its site should be very carefully selected so that it may be as secure as possible. No view from it is required.

Bringing Cables into a Fort.—Particular care must be taken in bringing the wires from the mines into a fort that they are not exposed to injury from projectiles. If necessary the channel in which they rest must be armour plated.

Electric Light Apparatus.—The electric light, as used to illuminate a channel, may be produced either by a 9 horse-power vertical engine driving two dynamo-electric machines by belts; by a Brotherhood engine combined with one or two dynamo-electric machines, to which it is coupled direct; or by a pair of horizontal engines driving one, and sometimes two, dynamo-electric machines, by belts.

In the first case the boiler is 9 feet high, exclusive of the chimney, and 3 feet 8 inches in diameter, and the whole apparatus can stand in a space of 21 feet by 8 feet.

In the second case the boiler is 6 feet or 8 feet high, and 4 feet or 3 feet 8¾ inches in diameter, and it is separate from the engine and dynamo machines, which are altogether 6 feet 10 inches long by 2 feet 8 inches wide; or 9 feet 3½ inches long by 2 feet 9 inches wide, and about 3 feet 7 inches high in each case.

In the third case the horizontal boilers are about 11 feet 6 inches long and 2 feet 9¾ inches diameter, and are placed usually 9 feet 3 inches centrally apart, the whole installation occupying an engine-room not less than 36 feet by 16 feet with a minimum height of 9 feet.

These machines should be under bombproof cover and should be protected against horizontal fire. A coal store will be required.

The position and arrangement of the electric lamp must be decided locally, but the type of emplacement is not yet fixed.

For further particulars see the *Manual of Submarine Mining.*

Electric Light for the Guns.—Owing to the development of position finding and the consequent increase in accuracy of coast artillery, it has become probable that night attacks will be resorted to by ships. To meet this electric lights must be provided for the guns. The lights would be divided into three sets; fixed beams for the mine field, under the direction of the R.E.; movable beams for the water in front of the mine field under the direction of the officer in charge of the Q.F. and other small guns; and other movable beams under the direction of the officer commanding the heavy gun defence. So much seems pretty clear, but the number required and their disposition is a matter for trial. Search lights should be kept very low down, but lights used merely to follow ships need not. They should not be near either to the batteries or to the position finders. The officer who directs the light practically commands the fire of the batteries, for it is only on the ships illuminated by it that the position finders can be laid. Consequently they should be worked from the position finder stations. Experiments have been made, and are being continued, and the Report of the R.A. and R.E. Works Committee on the subject contains information and recommendations intended to facilitate the preparation of projects for installations.

Angles of Depression for Firing.

A 64-pounder on a "colonial" sliding W.I. carriage, has been fired safely at an angle of depression of 20° 42′.

The carriage of a 9-inch 12-ton R.M.L. gun admits of 6½° depression, but with a slight alteration and a new elevating arc, the gun can be depressed to 14°, at which angle it has been safely fired.

The carriage of a 10-inch 18-ton R.M.L. gun will admit of 10° depression, but can be altered to admit of 14°, as with the 9-inch.

The 12·5 inch 38-ton R.M.L. gun can be depressed to 8°.

For B.L. guns H.P. mountings are usually made to admit of fire at 5° depression. If more be wanted special provision must be made for it in the mounting and in the form of the crest of the emplacement

Table Showing Approximate Cost of Guns, Mountings, and Ammunition.

Nature of Gun.	Weight. Tons.	Cost.				
		Gun.	Mounting.		200 Rounds of Ammunition.	Total.
			Barbette.	H.P. including Shields.		
		£	£	£	£	£
12·5-in. R.M.L.	38	3,328	1,454	—	1,700	6,482
11-in. ,,	25	2,110	991	—	1,130	4,231
10-in. ,,	18	1,330	933	—	880	3,143
9-in. ,,	12	910	676	—	584	2,170
13·5-in. B.L.	69	12,000	(?)	(?)	8,878	—
12-in. ,,	46	7,700	(?)	(?)	4,922	—
10-in. ,,	32	6,000	2,000 —	— 5,000	4,026	12,026 15,026
9·2-in ,,	22	4,225	2,000 —	— 4,500	2,896	9,121 11,620
8-in. ,,	14	2,400	1,200	—	1,508	5,108
6-in. ,,	5	1,000	1,000 —	— 1,700	914	2,914 3,614
5-in. ,,	2	570	(?)	(?)	312	—

Note.—These prices are not put forward as accurate, but they will serve as a guide to the cost of schemes of defence.

Permanent Fortification For English Engineers

LEWIS

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