R·E

PROFESSIONAL PAPERS

OF THE

CORPS OF ROYAL ENGINEERS.

EDITED BY

MAJOR R. H. VÊTCH, R.E.

ROYAL ENGINEERS INSTITUTE

OCCASIONAL PAPERS,

VOL. VII.

1882.

London:
PUBLISHED FOR THE ROYAL ENGINEERS INSTITUTE,
BY EDWARD STANFORD, 55, CHARING CROSS,
1883.

PREFACE.

Permanent Fortification is *par excellence* the art of the Military Engineer, and in these days of rapid progress in gunnery and small arms, he cannot be too grateful for any assistance that enables him to acquaint himself with all that is done to keep pace with this progress.

The principles of permanent fortification do not materially alter, but their application does, and although these principles have been instilled in early life into the Military Engineer, yet, in order to design and construct permanent works of defence, it behoves him to be informed of all the latest improvements in the arms and devices of the attack, and of all the details worked out and approved by the War Office for enabling the defence to meet these improvements.

But where is this information to be found? We believe we are right in saying that until now it could only be obtained by actual experience in constructing works, and by the acquaintance, thus acquired, with the instructions and details communicated by the War Office; of course, assisted by reference to various books, papers, and reports, many of which, however, are not very accessible.

Many officers who have shared our experience of the want of accessible information as to improvements and details will cordially welcome the present volume of our *Professional Papers* (Vol. VII.). It is entirely devoted to the subject of Permanent Fortification; the bulk of the work consisting of a course of lectures (illustrated by plates) which were delivered at the

Royal Engineers Institute, by Captain J. F. Lewis, R.E., of the Fortification Branch of the War Office, in the Spring of 1880, and which have been extended, corrected, and revised down to the Spring of 1882. To these lectures is added a paper, entitled "Notes on Armoured Defences," by Colonel T. Inglis, C.B., R.E., which is intended, by presenting to the reader a concise account of the introduction of the use of iron into permanent fortification and the history of its development, to supplement Captain Lewis's paper and to act as an index to the valuable papers contributed by Colonel Inglis to the *R.E. Professional Papers* as well as to other sources of information on the subject.

We believe we are now putting into the hands of the Officers of the Corps a thoroughly reliable text book on Permanent Fortification at the present time, and we desire to record our obligations to Colonel Inglis and Captain Lewis for the trouble and care they have bestowed in the preparation of these papers.

It must not be forgotten that alterations and modifications in the details of Permanent Fortification are continuously being made, as indeed they must be, in order to keep level with the advances made in the arms of precision, and that although this book is a reliable text-book to-day it may not be so long; but having established a basis which is reliable at this date, it will be comparatively easy to supplement it from time to time by a record of the advances and changes that have been made.

ROBT. H. VETCH, Major, R.E.,

Secretary, R.E. Institute, and Editor.

December, 1882.

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ON

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BY

CAPTAIN J. F. LEWIS, R.E.,

Delivered at the R.E. Institute, Chatham, in the Spring of 1880, and Extended, Corrected, and Revised down to the Spring of 1882.

AUTHOR'S PREFACE

Part of the following pages was given as Lectures at the Royal Engineers Institute, at Chatham, in March, 1880. Since then a considerable amount of matter has been added, but the division into Lectures has still been preserved.

The Author hopes that these notes will at least save his brother officers some of the unnecessary work over details that he himself has had to go through.

J. F. LEWIS,
CAPTAIN, R.E.

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PERMANENT FORTIFICATION.

A course of Lectures delivered at the R.E. Institute, Chatham, in the Spring of 1881,

BY CAPTAIN J. F. LEWIS, R.E.

LECTURE I.

1. PRELIMINARY REMARKS.

IN commencing these Lectures on Permanent Fortifications and the mode of constructing them, a few remarks may with advantage be made on the desirability of an acquaintance with the subject. It has been said that it is useless studying permanent fortification, as all our large fortresses are built already, and there would be no chance of a man applying any knowledge of the subject that he might acquire. This idea is quite a mistake. It is undoubtedly true that most of our great fortresses have been reconstructed of late years, or are in process of reconstruction, but in the first place none of these fortresses, even of those considered finished, are absolutely complete; in all of them additional works are desirable and will probably in time be provided, and the works already constructed often require modifications and additions to render them fit for the modern conditions of warfare. Then there are the defences of the large commercial harbours of the United Kingdom, which have hardly been touched of late years, to be revised, which in many cases rest as they were at the end of the Crimean War, during which a number of coast batteries were built. Then, again, there are the commercial ports in our colonies to be protected, some of which had defences hastily built during the time, in 1878-9, when there were anticipations of a war with Russia; and then, perhaps the largest question of all, there are those fortresses to be made which we require, dispersed in various parts of the world, besides Malta, Gibraltar, Bermuda and Halifax, upon which to base those naval operations on which our supremacy of the sea depends, a supremacy which is essential to our very existence as a nation.

The Colonial defences are now being considered by a Royal Commission, from whose recommendations, if they are carried out, must certainly come a good deal of permanent fortification.

Lastly, there are the defences of London, which if they ever are made, will require all the knowledge of fortification that the Corps can muster.

Perhaps, again, it may be thought that all large works are designed in London, and that all that the officers on the spot can have to do is to carry out cut and dried plans. This, however, is not at all the case. A fort can only be satisfactorily designed when the designer can study the actual ground, and knows the local conditions under which it will be built and defended. At the same time the improvements being made in weapons are constantly altering the conditions under which fortifications are constructed, and these improvements can be completely known only in the War Office; so that really the only way to make a good design is to pass the plans backward and forward, so that all available information may be brought to bear upon them.

In the case of casemated coast batteries certainly more has to be done from the War Office than in the case of other works, for most of the details used in them are the results of long series of experiments, and are found suitable to the requirements of the guns, and it is consequently desirable that they should be accurately the same in all places. Even in coast batteries, however, there is much to be done locally.

In 1878, when we were preparing for a possible war with Russia, a Lieutenant of Engineers of only eight years service had the entire responsibility of designing and building the fortifications of one of our most important coaling stations and commercial harbours in the East, with very little assistance in the way of plans, and with no Engineer establishment on the spot. He had to choose the positions for the works, design them, organize an establishment, collect workmen, make contracts, and in fact carry out the whole thing.

From all this it will be seen that there is plenty of work yet to be done, and that any one of us Engineers may be suddenly called upon to take a great part in doing it.

Moreover, though we have a great many trades, yet if anything can be said to be decidedly the business of a Military Engineer it is Permanent Fortification; he need not necessarily have Chemistry or Telegraphy or Submarine Mining at his fingers ends, but he should know the points of a Fort when he sees it, how to attack, and how to defend it.

Separation of Subject Matter.

In arranging the subject matter of these lectures it has been found 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 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 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 the guns actually mounted on them firing a single shot, for at certain periods of the 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 sea 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.

2. LAND FORTIFICATION.

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

This is a quotation from Colonel Hume's *Précis of Tactics*, and it 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, will probably require 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; and all the changes made in fortification have been the consequences of the improvements that have been made in weapons.

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

It will be recollected that the effective range of the S.B. musket limits 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 omitted, and new arrangements were introduced to meet the altered condition of affairs.

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.

Siege Artillery.

Siege guns and howitzers.—Our own siege train—and foreign ones resemble it—is composed of 64-prs. R.M.L., of 40-prs. R.M.L., of 25-prs., R.M.L., and of 8″ and 6″·6 R. howitzers. Long B.L. guns of the new type, firing projectiles at a high velocity, will, no doubt, be substituted for some or all of the guns in the above list, and a few 6″·6 guns are being now introduced, that are an improvement on the 64-prs.

The guns are intended for direct fire at parapets, and at the opposing artillery, and also at escarps if they are insufficiently covered. The howitzers are intended for breaching covered escarps and caponniers, and for searching out the interior of works.

The accuracy of these weapons is considerable, the new pattern of howitzer being much better than those first made.

A large amount of information as to ranges, angles of descent, accuracy and time of flight, will be found in the "Instructions for the Service of Siege Artillery, 1880," from which are extracted a few data for the 64-pr. of 64 cwt., with a 12-lb. charge, and 90-lb. projectile :—

Accuracy and angles of descent of 64-pounder projectiles.

			Fifty per cent. of rounds should fall within		
Range.	Elevation	Angle of descent.	Length.	Breadth.	Height.
Yards. 1000	1° 36′	1° 52′	Yards. 6·3	Yards. ·47	Yards. ·22
1500	2 41	3 7	10·9	·77	·70
2000	3 30	4 42	17·4	1·12	1·56
2500	5 6	6 36	26·5	1·51	3·10
3000	6 30	8 57	37·9	1·95	5·88
3500	8 5	12 3	51·7	2·57	10·17
4000	10 3	16 50	66·7	3·51	16·10

The "Manual of Siege and Garrison Artillery Exercises, 1879" may also be consulted.

The Reports of the Siege Operations Committee contain the records of numerous experiments, but being confidential they are not so useful as they might be.

The extreme penetration of guns of the present type, at short ranges, may be taken approximately as follows :—

Into Rubble—Penetration in feet a little less than the calibre in inches.

,, Brickwork.—Penetration in feet a little more than the calibre in inches.

,, Concrete.—The same as brickwork, if well made.

,, Earth.—Penetration in feet about four times the calibre in inches.

Penetration varies a good deal with the quality of the material fired at; but effects are mainly produced by the explosion of shells. The new high-velocity projectiles will no doubt penetrate much further than the old ones, under favourable circumstances, but they appear to be very easily deflected, and do not carry large bursting charges.

Effect of the 8″ R. howitzer.—The heavier weapons are very effective, the 8″ R. howitzer in particular, which has been much improved of late, and is capable of breaching an unseen escarp at 3,000 yards range; its heavy shell of 180 lbs. smashes any masonry it comes against at almost any angle of descent, or inclination to the normal, so that it may be taken for granted that any escarp not iron-faced, however sunk and covered, must succumb to the 8″ howitzer or any similar weapon in the hands of skilled artillerymen.

The effect on casemate roofs is not so great, particularly when they are covered with earth, for the explosion of the shell acts rather in an upward direction, and, moreover, the fragments tend to fall back into the crater. Only a few inches penetration would be obtained into a level surface of concrete, and any hard layer has a great effect in stopping a projectile.

The 6″·6 R. howitzer.—The 6″·6 R. howitzer is not nearly so effective as the 8″, but it is lighter, and therefore capable of being transported under circumstances in which the more powerful weapon could not be used.

Guns of the future.—There is likely to be a considerable addition of power to siege guns within the next few years, by the more general use of guns carried about in pieces and screwed together when wanted, the weights being thus reduced within manageable limits for transport. Very powerful howitzers, and guns capable of piercing from 12 to 16 inches of iron, will probably be brought into the field against any considerable fortress. As much strength should therefore in future be given to land works as to coast works not of the first class, as they may both have to resist guns of about the same power.

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, and high angle musketry fire becomes efficient at a range of 2,500 yards.

For accurate direct fire it is probably necessary to advance to within 1,500 yards, though this limit is likely to be exceeded by the new long B.L. guns.

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 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.

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.

With a numerous garrison the flanking fire of the works is of lessened importance, as the field force, which is 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 their 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 will 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 flank 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 the field force, but without any intermediate temporary works, to prevent the enemy marching into the place without having to silence any of them.

This in a fortress is the equivalent to making a fort secure against escalade; it ensures that the enemy shall not capture it before there has been time to prepare for him.

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

Having thus arrived 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, we have next to consider what additions should be made to them in order to resist a regular siege.

Works to resist a regular siege.—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 the 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.

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

Temporary batteries.—But a great deal of the work of the defence should be done from temporary batteries erected in such spots as may become suitable during the progress of the siege; for just try to realize the condition of an important fort 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 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. Nearer, about 1,500 yards off, can just be distinguished the crests of two or three batteries, the guns of which only appear when they are ready to fire; these are trying to cut down your parapet 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 caponnier that the escarp is beginning to get knocked about with the fire of the heavy howitzer shells, and the roof of the caponnier itself has had a bad hit or two. The face of the parapet is decidedly out of shape, especially where the counter-battery has begun cutting a way into one of the disappearing-gun pits; 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 will be necessary for the fort to fire at the approaches as it will have a good command over them, which the ground outside will not, and, moreover, it will become difficult to hold those outlying batteries which are near the fort attacked, 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.

Temporary batteries.—The besieged therefore should dispose his guns 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 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 must be used in the first period of the attack because there are no others mounted, and in the last period of the attack because the fort is then 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 be of the usual siege type, and will be armed with guns mounted on siege carriages of various patterns.

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

The flank guns are all to be mounted; a few of the guns on the faces are also to be mounted on some type of disappearing carriage, either counterweight or hydro-pneumatic, or, for future constructions, on a new permanent disappearing carriage.

The remainder of the guns and all the rifled howitzers will be kept in the forts 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 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, in order that in considering the designs of permanent works all the forms of attack which they may have to meet may 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.

An open 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, and more especially their flanking defences.

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 what the strongest works are designed to resist as long as may be.

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 not seriously, unless they were very numerous. Attempts would 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 would have to be assaulted and taken, but a very determined resistance is not to be expected, as on the defender's 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 on the accidents of the ground. It is seldom that the guns of a fort have an unrestricted field of fire up to the limit of their effective range; there is almost always some feature 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 *materièl.* 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 may 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, no doubt, be used.

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 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 may 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.

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 their artillery.

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 necessary to take a single one only.

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 two or three hundred yards in front of the forts.

The first parallel will be made by flying sap, 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 besiegers' 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 may be made 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 of the second artillery position are taken in hand. They would be about 1,500 yards from the fortress, and most probably covered by the first parallel. These will be few in number, for the difficulty of protecting the guns at such a short distance will be very great, and, besides, most of 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 decrease of range will be valuable. It is probable that it will be necessary to mount the guns on some form of disappearing carriage.

The besieged will probably endeavour to meet this fire with light guns and wall-pieces, 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.

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.

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. It will be a great thing for the besieged at this time if they can get a light gun or a heavy wall piece into action, as it must stop the sapping.

It is probable that some of the large-bore machine 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.

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 caponnier, 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.

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. They should be from 30 feet to 60 feet wide.

With good rifled howitzers and careful firing they may be made either from the first or second artillery position, though naturally the firing is likely to be most accurate from the latter.

Assault.—The breaches having been made, the descent into the ditch completed, and the flanking defences destroyed, the assault must be delivered, preceeded 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 must 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 its guns effectively, both at long and short ranges, both to the front and to the flank; and must be able to oppose a stubborn resistance to the last stages of the attack, including crossing the ditch; and, in addition, must contain secure accommodation for its garrison, ammunition, and stores, and for the guns of the field works which will be kept there; 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.

Such a work is here described, and afterwards the modifications in the plan, rendered necessary by some of the varied conditions under which fortifications are employed, are considered.

Large Detached Fort.

Large detached fort.—Plates III. and IV.—The plan which has been chosen as illustrating the features to be embodied in a fort is modified from one which is no doubt familiar to many of you, as it was drawn for the use of the Royal Military Academy and lithographed there on a small scale.

A great deal of pains was taken with that design originally and it has not been altered essentially; the modifications being intended to provide against the development of artillery fire made since the design was first prepared. The chief of these, as you will at once see, is in the ditch with its flanking defences, which have been arranged on a different principle to that adopted in the original.

You must not however suppose that this plan would meet with universal acceptance.

Like all other projects for fortification it is an attempt to combine contradictory qualities; to see without being seen; to have large masses of rampart with guns firing in all necessary directions, and at the same time nothing for the enemy to strike; to have casemates which shall let in light and air and yet be perfectly secure against shells; to have plenty of parapet space, and yet plenty of traverses; to be secure against assault, while recognising the fact that it is impossible to build a perfectly protected escarp.

Different people give different amounts of weight to the various elements of the problem to be solved, and their solutions will differ accordingly. Experience is the only certain guide, and even the results of experience require careful weighing, so that the varying conditions may have their proper influence, and that we may not be led into curing an evil, although an undoubted one, by an alteration which will introduce a worse one in its place.

Fortification is essentially a matter of compromise. The best fort is that which, built in a given situation, and with the expenditure of a given sum of money, can hold out longest.

On every site the conditions change, and the design should be modified with them, so that designs and sites are not interchangeable.

The best designed fortress is that in which the forts are in due relation to one another, and in which the strongest works are placed in the important positions, so that we may not find a good fort in a place where it is too strong for the work it has to do. But the fort itself must be judged independently of this; the question is, has the money—that is the labour—spent on it, been laid out to the best advantage, or could a longer resistance have been ensured by a different arrangement of its parts?

The work shewn on *Plates* III. and IV. was designed on the supposition that it stood on a rounded hill with easy slopes. This is the best supposition to make in designing abstract works, since a level site is rarely met with in reality. Outlines can be given to forts constructed on level sites which cannot be used if there is any irregularity in the ground, and a design made for level ground may therefore not suit any other position.

It is also supposed not to be standing alone, but to be one of a ring of detached forts, and therefore not immediately liable to an attack in flank.

Objects aimed at.—The objects sought to be attained in the design are the following:—

1. A strong front parapet.
2. A sufficiency of direct fire.
3. A powerful flanking fire of artillery which it shall be difficult to silence.
4. A convenient and secure position from which to deliver indirect fire.
5. A gorge, the attack of which shall require the use of artillery.
6. Forms of earthwork generally, which shall give the maximum resistance against projectiles.
7. Secure casemate accommodation.
8. Secure magazines and convenient ammunition service.

9. A sufficiency of bomb-proof cover on the ramparts.

10. Secure and convenient communications.

In the original design an attempt was made to get an escarp that could not be breached, and a good deal was sacrificed to that end in width of ditches and power of flanks; and for a time the attempt was successful, but the increased accuracy of fire has finally rendered it impossible; in this fort therefore the necessary end of security against assault has been sought in a different manner, which will be explained further on.

An idea of the size of the work may be given by saying that it is rather larger than Fort Borstal, and is somewhat smaller than Fort Horsted is designed to be. The front faces are 180 feet long, and there is nearly 600 feet between the gun pits on the two flanks.

I will now proceed to point out how far the objects mentioned have been realized.

1. *Front parapet.*—The strong front parapet has been obtained by making it almost entirely solid, with hardly any casemates in it, and with easy slopes, so that no amount of battering can be capable of doing much beyond disturbing the earth, which might be replaced, or possibly formed in a different shape, if the fire slackened and an opportunity offered itself.

2. *Direct fire.*—A sufficiency of direct fire for the commencement of a siege has been obtained by providing three disappearing gun pits, one in the centre salient, the two others on the shoulders, also two finished emplacements for guns on siege-disappearing carriages, and parapet space for light guns which could be made available with a few minutes' work.

The siege-disappearing guns, and some of the light guns, should be kept in the bombproofs in the rampart, so as to be always ready.

At the end of a siege it is probable that the permanent disappearing guns will have been silenced, though every effort should be made to preserve them. The siege-disappearing carriages will still be available as they should be removed under cover as soon as they can be dispensed with at the beginning of the attack. If their emplacements are destroyed others can be improvised. Some light guns will of course be still available.

There is space on the parapet to mount 16 guns.

The howitzers are always available for curved fire, but they are not such suitable weapons as guns for use at the beginning of a siege, before the enemy's objects have been declared.

3. *Flanking artillery.*—The flank fire of artillery is unusually powerful, for not only can all the permanently mounted guns fire to a flank, but the chief feature of the fort is the casemated battery of 4 guns on each flank. These are protected from reverse and enfilade fire in the only way in which it is possible to do so satisfactorily; that is by arching them over. No parados or traverse can give more than a very partial security.

The perfect protection given to these guns in rear enables the direction of the face to be thrown back, so as to increase the difficulty of striking its front. The lines of fire of the guns are intended to be laid out so that they may cover the ground between and about the adjacent forts; it would not be possible for the enemy to fire directly at them unless he erected batteries near the front of the next work, that is unless he brought his guns nearer the line of the defences than it would be necessary for him to do if he wished only to subdue the front fire of the works.

The casemates are shewn covered with iron girders and plates instead of arches; this is in order to keep them as low as possible. If economy be an object, the walls only may be built, and the roofing with iron or wood done when the fort is prepared for defence.

The ends of the flanks are finished with a short piece of musketry parapet of which there should be enough in a fort to obtain a look out in all directions, for the field of view from a casemate is limited. The small arm fire from a casemate will, however, in future probably become very powerful, as it will be delivered from machine guns, which could be used either on their tripods, or on a socket-mounting fixed in the embrasure.

4. *Howitzer battery.*—A convenient and secure position for the howitzers is obtained by carrying a parapet across the centre of the work behind which they can be mounted. This is better than placing them about on the parade, or putting them close behind the front rampart, where firing them might be inconvenient to the men upon it. Of course, the device of turning the guns on the rear faces round, and firing over the front for indirect fire, though used with success by the French in the war with Germany, is essentially a temporary expedient.

The crest of the parapet of the howitzer battery should be kept lower than that of the front of the work so that it may be unseen by the enemy, and that he may have no indication of the exact spot from which the fire is proceeding, or of the success of his attempts to silence it.

The howitzer battery serves to some extent as a retrenchment, but nothing has been done to adapt it specially for this. It would spoil the work for its proper purpose. The best retrenchment is another work in rear.

5. *The gorge.*—The gorge has been given a section as strong as that of the faces of many old works, and there are no openings in it except for the entrance which must of course be there, and the embrasures of the flanks.

The dwelling casemates, which are often constructed along the gorge, are in this case kept in the interior of the work. The entrance is protected by a covered way and place of arms.

This amount of strength is given to the gorge in order to force the enemy to attack it with artillery if he attempt it at all.

In many cases, where works are rather close together for instance, this precaution may be unnecessary, and then the dwelling casemates can be put in the gorge, which is a convenient place for them; but if a work be isolated, it might in some cases be quite a practical thing to attempt to carry it by the gorge, and this should be guarded against.

It will be observed that the gorge is thrown into a bastioned form with the flanks casemated in two tiers, and the entrance in the centre. This will be found a strong and convenient arrangement. It enables a heavy cross fire to be brought to bear on the bridge, and in front of the entrance, and, by the use of escarp galleries, both economy of construction, and convenience of access and supervision is obtained.

The gorge is protected by a parados from fire from the front; this is, of course, not a perfect protection, but, as it is not likely that fire would be directed at the gorge from the front at the same time that it was being attacked in rear, and as neither the gorge parapet nor the parados would be visible from the enemy's batteries, it appears to be sufficient. If more cover were required, the gorge or part of it, might be treated like the casemated flanks, or the parados might be brought much closer up to the parapet.

6. *Earthworks.*—Great attention has been given to the disposition of the earthwork. The slopes are all very flat, the exterior slope of the parapet being $\frac{2}{3}$, and the parapet of the howitzer battery, with as

much as possible of the parados covering the gorge parapet is at a slope of $\frac{1}{7}$.

This glacis-like form given to the parapet of the howitzer battery is a special feature of the design, and is intended to minimize the probable amount of injury to men on the front parapet, caused by fragments of shell flying back on them, and every possible opportunity has been given to shells to ricochet, or if they do bury themselves, to burst upwards.

It may be observed, with regard to the earthworks of fortifications generally, that all long slopes should be flatter than 1 in 1, this inclination being reserved, if possible, for the rear slopes of ramparts and traverses, and such places as are not exposed to be struck by projectiles. It is seldom that any material will stand permanently at a slope of 1 in 1, and it must always be remembered that the slopes of a fort have not merely to stand under ordinary circumstances, but to do so, if possible, when battered by projectiles. Exterior slopes should never be steeper than 4 in 5, and may be with advantage 2 in 3, or even flatter, if local circumstances are favourable.

It will probably be observed that there is hardly any parade in this work; but as a parade is perfectly useless during a siege, on account of the projectiles that fall on it, it did not seem worth while having any, except a small one in front of the dwelling casemates.

7. *Dwelling casemates.*—The dwelling casemates have been placed principally under the howitzer battery, where they are even less liable to be breached than if they were under the front parapet, however thick that might be.

They are also fairly secure from fire coming from the flanks or rear, as they are well covered by the gorge.

A portion of the front of the casemates is covered by an arched passage, which prevents the possibility of projectiles fired at the entrance gate from the rear passing right down the whole length of the central passage, and so into the caponnier.

The arched passage also acts as a traverse, tending to localise the effects of any shell that may fall in the parade. Of course it is objectionable, in that it cuts off light from two casemates; but it is an arrangement that it will be often necessary to resort to in future constructions in order to get security.

There are a few small casemates under the ramps which face to the front. It was convenient to put them there; they are well defiladed, and must take their chance. They would be useful as stores.

A few casemates have been placed under the front parapet. That was done in order to be able to keep a guard as close up to the front as possible.

Besides the proper dwelling casemates, there is plenty of bombproof accommodation in the passages, caponniers, and casemated traverses, all of which would be used for men and *materièl* during a siege.

8. *Magazines.*—The main magazine and the main shell-store have been placed under the interior glacis, instead of under the casemates of the flanks, as in the original design.

They are not now covered by such a great thickness of earth as before, but it is quite sufficient, and two advantages are gained—the entrances are better protected, and it is easier to get at the roof of the magazine for repairs.

There will be more on this subject in a later lecture.

The service of ammunition from the main stores to all parts of the fort can be carried on nearly all the way through arched passages, and, therefore, in security from the enemy's projectiles.

One element of danger has been introduced by the change of position of the ammunition stores, namely, that there is now a continuous arched communication between the main magazine and an expense cartridge store. This should be avoided, if it be possible, as an expense cartridge store is in some degree liable to explosion, and if under the same roof as another magazine the flame might communicate from one to the other. In this particular case the risk is much reduced, owing to the numerous ways in which the gases resulting from the explosion of the expense store may escape.

The expense cartridge stores are all placed under the terreplein level, and not behind the parapet or in traverses. It is no longer practicable to ensure their safety in the latter position, which, from its convenience, used to be the one most generally adopted.

The ammunition is sent up to the terreplein by lifts, issuing in bombproof traverses, so that they may be as safe as they can be made. Some details concerning lifts will be given in a later lecture.

From the heads of the lifts the metal-lined cases containing the cartridges would be taken to the guns, and deposited in recesses, made either permanently or temporarily in the parapet, in the ends of the traverses, or in the bombproofs, from which the guns would be supplied with charges as required.

The guns on the right and left faces would be supplied with cartridges brought either along the rear of the rampart from the expense cartridge stores in the centre, or down the lateral communications from the expense cartridge stores under the howitzer battery.

There are thus three resting-places for the cartridge on its way to the gun—the main magazine, the expense cartridge store, the cartridge recess.

Of these, the main magazine should contain the authorised proportion of ammunition for the guns allotted to the fort; the expense cartridge store should contain at least enough cartridges for a day's firing of the guns near it; the recess should contain at least two cases. (See Lecture III.)

The shells may still be stored in small quantities in the bombproofs in the terreplein, and also in recesses, as they are not so liable to be exploded as powder in cases, and this is the arrangement adopted in this work. At the same time, if it suits the construction to make the shell stores down below, it is as well to put them there, and serve them in the same way as cartridges.

If it be wished during the siege, the shells can be served up the cartridge lifts.

The shell stores, main and expense, together should hold the whole authorised number of shells for the guns, for the shells will all be filled if they can be kept in security.

9. *Bombproofs on the ramparts.*—The bombproofs on the ramparts, under the traverses, are six in number behind the front parapet, and four in the howitzer battery. Some of them contain stairs and ammunition lifts; others, on the front, are intended to receive such of the guns of the moveable armament as it may be thought desirable to keep ready for use on the rampart. They are all available for sheltering the men on duty there, if the fire becomes very hot, and if there be no object to be gained by immediately replying to it.

The reliefs for these men would be stationed in the casemates under the front faces.

10. *Communications.*—The communications are, perhaps, the most important part of a fort, and certainly the most difficult to arrange.

In the present case, the main entrance leads directly into a small parade in front of the dwelling casemates, where there is room for carts to turn and to set down their loads.

From this parade all the communications radiate. Leading to the front parapet there are three broad galleries—one on each flank of the dwelling casemates, rising a little to the general level of the ground in rear of the rampart; one in the centre, descending towards the front block of casemates, from the area in front of which there are ramps rising right and left to the ground level.

The terreplein of the rampart is reached by ramps convenient for taking guns up, by short sets of steps up the slopes for the men, and by stairs leading up from the casemates into a bombproof in one of the central traverses, by which a secure access to the terreplein is obtained.

The openings of the right and left galleries are to a certain extent protected by traverses, which also assist in covering the approaches to the terrepleins of the right and left faces.

The way to the howitzer battery is up ramps on the right and left, and also up stairs leading into the traverses.

From the howitzer battery there is a way into each of the casemated batteries, and from these into the disappearing gun pits at the shoulders of the work. There is no direct communication between these gun pits and the front parapet, the work there being left as solid as possible.

There is a way all round the gorge from one casemated battery to the other.

The lateral caponniers are approached by galleries leading from the parade in front of the dwelling casemates; the men defending the ditch thus get a somewhat more secure retreat than if the galleries opened behind the front rampart, for the howitzer battery acts to a certain extent as a retrenchment.

The additional security gained is not great, but it is desirable to adopt any means that tends to give confidence to the troops.

It must always be kept in mind that fighting now-a-days is almost invariably decided by moral effect. It is the moral effect produced in one man's mind by seeing another man shot that induces him to run away; fighting is seldom pushed to the extremity of slaughtering the whole of the defeated party. Consequently, particular attention should always be given to any device which will tend to give the troops confidence.

The centre caponnier communicates with the casemates under the front parapet and so with the rear of the work. The access to these casemates is somewhat roundabout for an enemy, and the approach to them so well covered by fire from the howitzer battery, that it was not thought worth while to have an independent gallery of approach to this caponnier.

From the galleries leading to the caponniers which flank the ditches in front of the casemated guns, sallyports are opened into the ditch. These are necessary in order to reach the mine galleries which would start from the counterscarp, unless it be preferred to commence them from the ends of the caponniers, or from the counterscarp galleries in cases where the latter are used. It is, however, better as a rule to keep two different kinds of defence separate.

These sallyports are of course a source of weakness. They should be concealed as much as possible, well flanked, and closed with bar gates and loopholed gates, or with a drawbridge.

11. *Defences of the ditch.*—The chief novelty in the fort is the nature of the defence of the ditch, which is arranged on somewhat different principles to those that have hitherto been followed; the change has been forced by the increased accuracy of rifled ordnance.

The assumption, by-the-bye, is that this ditch is excavated in earth not in rock. A rock-cut ditch can be treated quite differently.

The reasons that have led to the construction shewn are the following:—It is hopeless any longer to expect to preserve any masonry construction, which faces at all to the front in the ditch, safe from being breached; that is, if the attack be made by skilled artillerymen with proper weapons. At the same time it is essential that the fort should be secure from escalade, and that the passage of the ditch should be rendered as difficult as possible against all forms of attack.

Security against escalade is indeed the principal advantage which should be possessed by a permanent work as compared with a field work; it is possible to construct in haste good parapets, fair bomb-proofs, and even tolerably secure magazines, but not revetted escarps or counterscarps, or powerful caponniers. Care should therefore be taken to preserve this advantage in permanent works.

The solution of the problem which is here put forward is to use wide ditches, admitting of long and powerful caponniers, the latter being made of the minimum dimensions in cross section, and with strong iron roofs in the most exposed parts; thus being screened from view they would be difficult to hit, and if hit would in most cases deflect the shot.

There is a good counterscarp 25 feet high, which is an obstacle that cannot be breached, except on the side of the fort furthest from the enemy, and which shelters the caponniers from view; and, finally, there is a detached wall running down the ditch, flanked on both sides from the caponniers. This wall is a very efficient obstacle while it lasts, and it can only be destroyed by the careful curved fire of artillery. The fort, therefore, to begin with, is as secure against escalade as any work of the ordinary construction, and this advantage it retains until the enemy has constructed breaching batteries and ruined the detached wall.

This will at least give plenty of warning to the besieged, and when it is gone they must do their best with a good counterscarp and unusually powerful flanks.

The fall of the wall involves nothing else, and with a few days respite it might even be re-built.

The wall might be replaced by an iron railing, which would probably be more difficult to destroy, but would also be more expensive. Railings should in any case be used for the portions near the caponniers, as, otherwise, fallen fragments of the wall might interfere with the fire.

The iron caponniers will be about 10 feet wide, which gives room for the B. L. 32-pounder flanking gun on a non-recoil carriage, and they will provide loop-holes for rifles about 4 feet above the level of the bottom of the ditch, and also loop-holes about 2 feet above it for Gardner machine guns, the slope up to them being formed in concrete. This gives a large amount of small arm fire.

There is just enough headway inside to stand comfortably, and the compound iron and steel covering plates are considerably curved so as to increase the chance of deflecting shots.

The cost is somewhat heavy, for which reason an ordinary masonry construction has been substituted for iron in all situations where it seemed sufficiently secure.

Iron has been retained in all the caponniers for the portion on each side of the detached wall, which is the most important part and most exposed to fire, and where the use of the iron construction enables reverse loop-holes to be made from which the exterior slope can be commanded.

Modifications of Design of Fort.

Having thus noticed the chief features of the design before you, with the reasons which led to their adoption, we will proceed to consider some of the modifications that may be introduced in practice.

Small detached fort.—The small fort shewn in *Plate* V. was designed for an actual site on the same principles as the larger work.

The ground is nearly level for some distance round, but with a depression on the left flank.

The work is intended to guard a coast battery behind it from a land attack, and it is not far distant from it; consequently it has not been thought necessary to give it a powerful gorge, and the casemates have been placed in the rear of the fort. This is economical, and enables the size of the work to be reduced by bringing the parapet of the howitzer battery back as a parados to the gorge parapet. All the guns can fire to one flank or the other, so that the flank fire is powerful, although the row of four casemates in the larger design has dwindled down to one in this.

There are escarp and counterscarp and masonry caponniers. The escarp and the caponniers are safe from all projectiles except those falling at a greater inclination than 1 in 4, and at a less horizontal angle with the face of the wall than 30°. This is safety enough for most cases; it would require good weapons and accurate fire to effect a breach. The form of ditch shewn in *Plates* III. and IV. could be adopted if wished.

In details the small fort resembles the large one.

Fort Horsted.—Another work for which designs have been made on similar principles is Fort Horsted, one of the Chatham defences on the Maidstone road. In this case, owing to the irregularity of the site, the casemated battery is much larger on the left flank than on the right, five guns against two, and this flank is not retired as in the model fort since it is not liable to a front attack.

This fort being in a somewhat salient position, another feature has been introduced, namely, a large central traverse, such as the Germans use in their works, running from front to rear. This gives some protection against enfilade fire, and localizes the effects of shells.

The parapet of the howitzer battery has been brought back to cover the gorge, as in the small fort in *Plate* V.

The casemates are also put in the gorge; for the works are so near Chatham that it is impossible to admit of the supposition that the enemy could penetrate behind them, and moreover they are so close together that it is not likely he would be able to; consequently the gorge need not be capable of resisting artillery.

The whole work will be rather larger than the large detached fort shewn in *Plates* III. and IV.

A work on a heptagon.—A work has recently been designed on similar principles, traced on what is very nearly a regular heptagon. The traverses and parados of the rear faces are arranged to give much more protection than in the other forts mentioned.

From these examples it may be seen that forts can be constructed on the principles, and with many of the details shewn above, and yet with considerable variety of arrangement and adapted to various kinds of ground.

Modifications of typical design.—For forts which are special in their objects particular features of these designs only need be taken, and the unnecessary ones suppressed or reduced.

Flanking fort.—For instance, in a work wanted mainly for flanking a position, the direct fire being given from elsewhere, the casemated flanks may be brought closer together or the front parapet simplified and cheapened.

The howitzer battery might disappear or be reduced to a parados to the gorge.

Fort for direct fire.—In a work required mainly to deliver a direct fire on the enemy's approaches, all the attention must be given to the front parapet, so that the guns mounted there may remain efficient for as long a time as possible. In this case it would be well to have bomb-proof cover for all the guns in the traverses, and an arched gallery underneath the rampart, with stairs leading to each of the traverses.

The faces should be made as long as possible and the depth of the fort kept at a minimum, something, in fact, like the German type.

The casemates might be put under the front parapet so as to save depth in the work, and the howitzer battery might perhaps be omitted, the indirect fire being given from elsewhere.

The character of the ditch defence depends in each case on the nature of the attack to which the work is liable, but every fort and battery should be surrounded by some obstacle, if it be only to keep out the little boys of the neighbourhood.

Some works may be so situated that it would not be worth while for an enemy to devote much time or labour to their capture, and if in these cases the defences of the ditch are sufficiently strong to render it necessary to erect batteries in order to demolish them they may be considered safe. Iron caponniers and such precautions are only necessary for works likely to have to resist a systematic attack.

It may sometimes be advisable to organize carefully the ditch defence of an outwork; in the case, that is, in which its capture is the necessary preliminary to the attack on the main work. An outwork should not necessarily be comparatively weak; its strength must be proportioned to the attack likely to be made on it.

All permanent land works should be secure against a sudden assault, and even if a work be protected by a continuous line or obstacle in front of it, it should be arranged so as to be capable of acting as a retrenchment in case the obstacle be passed.

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 organized 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 organization of the rampart will depend on 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 in a fort, there is not the same objection to cutting it up with numerous traverses.

If the curvature of the line be slight the organization 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.—In this latter case part of the problem of the ditch defence becomes comparatively easy, as it is possible to use a high counterscarp to form the obstacle. This cannot be done in a detached fort because the counterscarp on the flanks can be breached from the front just as easily as the escarp can on the faces, but when the ditch is safe from reverse fire the counterscarp can be made use of.

The flanks, whether caponniers or counterscarp casemates, will be pretty secure from artillery fire if placed at the salients, although the ditches must be exposed to enfilade from somewhere; the line may be traced *en tenaille*, that is in a zig-zag form, to increase their security in this respect.

Unfortunately, though, any attack must necessarily be directed on the salients, for which reason it is expedient that the flanks should be elsewhere; therefore, in cases where a close attack is to be feared, some other position had better be found, the centre of a straight face perhaps.

Another way of treating the problem is to throw the parapet into the form of a series of very flat bastions, the ditch being *en tenaille* with caponniers at the salients. The caponniers will then be serviceable until the enemy actually begins to prepare for the crossing of the ditch. The defenders might then retrench the salient and defend the ditch from the remains of the flanks of the bastions; these would have been all knocked out of form of course, but rifle pits might be constructed in the debris, and from the way in which the work was laid out there should be no obstacle to the view of the ditch.

Cross fire on the glacis.—It is in any case advisable to adopt a bastioned or indented form for the parapet of a continuous line, in order to get the advantage of a cross fire in the ground in front.

It may be desirable in places to have the additional cross fire which may be got by means of ravelins, but such works should always be placed where they are not exposed to a direct attack, as their offensive power to the front is almost nil, and the flank defence of their ditches cannot be satisfactory, whether it be got from the parapet of the main work or from counterscarp galleries in the salient.

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 no howitzer battery, and need not contain many casemates.

Such advanced lunettes may be constructed before the caponniers of the main line, to which they would give great additional security.

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

The Use of Continuous Lines.

It is a matter of some interest to define exactly the case in which a continuous line should be used, for though all civilised nations, without exception, have adopted detached forts as the chief feature of their fortresses, whether permanent or improvised, yet it has been asserted that they are all quite wrong, and that continuous lines should have been built in place of them.

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 are 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.

Even if it were conceivable that he should be able to press on and drive back the force opposing him between the forts, he would still, if there were an enceinte, as there should be, have to attack it with some deliberation, and everything to be used in this operation would have to pass under the fire 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 absolutely 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 necesssary 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. I may here, perhaps, be allowed to mention that I have made designs and estimates for between 11 and 12 miles of continuous line, part of which is being built.

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 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.

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.

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.

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 develope 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 new works at Malta.

When a covered way is made of such importance as this, its parapet will require organising 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.

7. 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, and something must be said about it here, although it is difficult to say anything to good purpose, the number and variety of the conditions bearing on it rendering it impossible to lay down any general rules.

Typical modern fortress.—The typical modern fortress is one with an interior enceinte surrounding the town, arsenal, or dockyard, to be defended, and with an outer ring of detached forts; the ground in between being generally under fire, either from the forts or the enceinte.

In this combination, the enciente serves as a second line of defence in case any of the forts are taken, and also renders it useless for the enemy to attempt to possess himself of the town by passing a body of men between the forts.

The forts keep the enemy out of bombarding range of the place.

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

The enceinte.—Taking the enceinte first, 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.

The latter condition should not be considered one proper to stand a siege in; if no enceinte has originally been constructed, one should be made on a field trace, as soon as men can be spared from the more pressing work of putting the line of forts in a state of defence. 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*, but one or two of the forts must be captured in order to establish batteries against the enceinte.

Conversely if there be a permanent enceinte to a place, the outlying forts may be further apart than it would otherwise be necessary to place them.

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 the 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 improved 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 encéinte, something may 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 the 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.

If the ground be favourable the enceinte may be postponed.—If the ground be very favourable or the buildings of the town well adapted for defence the construction of the enceinte may be deferred until it is actually wanted.

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.

Inner line of detached forts.—An inner line of detached works sometimes takes the place of the enceinte. They must not be far apart, and it would be advisable to connect them at least by field works.

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 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 between detached forts and enceinte.—The distance which should separate the detached forts from the 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. Perhaps the works may be set in a zig-zag line, alternately advanced and retired, or they may be grouped with several advanced works depending on one central one; or there may be occasional works constructed in rear of the advanced line and supporting it. This last 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.

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 in the case of some very uneven ground which it was, nevertheless, necessary to defend in detail, owing 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 lines 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.

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.

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 have good ditches 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 works 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.

Calculation of the Armament of a Fortress.

It is impossible to lay down general rules for this calculation, 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 garrison. 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 lecture 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 temporary 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 not.

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, and it is probable that in most cases but small additions would have to be made to the numbers that would thus become available.

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

LECTURE II.

(This Lecture treats of the various constructive details of Land Works.)

1. MODES OF MOUNTING GUNS.

THE modes of mounting medium rifled and other guns on land works are rather numerous, as they have recently been increased by several new patterns of carriages and platforms.

Their nature, and the emplacement needed for each, will be shortly described, beginning with the medium guns, which are the rifled guns weighing from about 3 tons up to 5 tons, such as the 64-prs., and 80-prs. R.M.L., and 7-in. R.B.L.

Garrison standing carriage.—There are a good many guns still mounted on carriages of this nature, including a number of converted 64-pounders, and it may still be used in retired flanks for guns either firing through an embrasure or from a casemate. It may also be used for mounting some of the guns of a fort, which are not intended to be placed on the front faces but to be used 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 on it will fire over a sill 2 feet 3 inches high.

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

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

If the former, 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, though it will be gradually superseded in these positions by the two patterns of shortened platform which will be described presently.

If the latter, the gun will fire over a height of sill of 4 feet 3 inches. The mounting is thus suited for use in a barbette emplacement, or for a gun 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 unimportant positions, but it should no longer be used for land works at all.

Racers for 16-foot traversing platforms.—The radii of the racers for these platforms, with their distinguishing letters, are given below.—

RADII OF RACERS.

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

Casemate traversing platforms are not used with other than A pivot racers.

Dwarf traversing platforms 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.

The racers are flanged; the flange is $6\frac{1}{2}$ 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.

The top of the flange should be laid level with the top of the racer curb.

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 drawings of these racers see Inspector General of Fortification's Circular, No. 250, dated 26th September, 1876.

Pivot block for medium guns, firing over a height of 4 feet 3 inches.—It has been decided that all medium guns mounted on C, D, E, or F pivot racers are to be provided with actual pivots.

This consists of a cast iron pivot block, into which a steel pivot plug, 3 inches in diameter, fits, passing through a plate on the under side of the platform. 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 surface of the racer.

For a drawing see Inspector General of Fortification's Circular, No. 275, dated 13th May, 1878.

The spaces required to be kept clear for a 16-foot traversing platform, 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.

	ft.	in.
From the pivot to the front ...	10	0

Improved 16-foot platform.—An improvement in the 16-foot platform has been recently suggested which is likely to be adopted, and which will give much more security to the gun-detachment than they now possess. It consists, firstly, in blocking up the slide $7\frac{1}{2}$ inches; this enables the parapet to be raised to a height of 5 feet above the top of the racer blocks, thus increasing the protection of the men traversing and elevating; and, secondly, in altering the elevating gear so that the gun can be loaded under cover at depression. A small sunken way would be formed in front of the racer blocks in which the men would stand while loading. The depth of this depends on the amount of depression that can be given to the gun; what this can be is not yet settled, but if it be 10° the depth of the sunken way might be 9 inches, thus giving 5 feet 9 inches of cover behind the parapet. The high pivot block, 18·375 inches, should be used, as for the 6-foot parapet platform (see p. 52). It will be necessary to form the C pivot emplacement with a radius of 9 feet in order to give space for the men to load.

This alteration could probably be applied to all but B pivot emplacements.

New patterns of traversing platform.—The new traversing platforms, which are being substituted in some cases for the old 16-foot one, are the shortened 13-foot, the shortened 11-foot, and the 6-foot parapet platform.

Shortened platform, 13-foot.—The shortened platform, 13-foot, is adapted for use with the converted 64-pr. and 80-pr. guns, and with the 7-inch R.B.L. It is the old 16-foot platform with 3 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 platform works on the same racers as the old 16-ft.

The advantages gained by reducing the length of the platform are that with the casemate platform, 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 platform, it can, when on a C pivot racer, work all round the circle, so that with the shortened 13-foot platform the D pivot is no longer necessary. For with a 16-foot platform the parapet would have to be built with a radius only just sufficient to admit the tail of the platform, in order that the muzzle of the gun may project over it when in firing position, and this is inconvenient for working the gun, but an additional 3 feet of space makes all the difference.

In a C pivot emplacement, with a 16-foot or 13-foot platform, the radius of the path of the muzzle of a 64-pr. R.M.L. gun, when run up, measured from the pivot, is about 11 feet.

Shortened platform, 11-foot.—The shortened platform, 11-foot, is a new construction, intended to take the 7-inch R.B.L. gun.

It 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, and the dimensions are therefore as small as possible. This is a mode of mounting which will only be used in Great Britain, for the 7-inch R.B.L. gun is being withdrawn from all foreign stations.

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.

Slides for $6\frac{1}{2}$-ton guns, converted.—Since writing the above, it has been decided to utilize in these situations the carriages and slides of the 7-inch $6\frac{1}{2}$-ton guns discarded by 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 platform does.

Platform, 6-foot parapet. (*Plate* VII.)—The 6-foot parapet platform is one especially designed for use in coast batteries, and for this purpose is the best mode of mounting that we possess. It is described in this place in order to keep all the modes of mounting medium guns together. It is of entirely novel construction and mode of working. The material is of 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. The recoil is checked by a circular hydraulic buffer, a device which, though not found to be suitable for heavy guns, is quite successful on this scale. 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 platform is 13 feet 2 inches long, and is mounted on the same racers as the old 16-foot platform.

Pivot block.—The pivot block is, however, 18·375 inches high instead of $12\frac{1}{4}$ inches.

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 6 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 or a rope rammer. The gun has been fired at a depression of 22° 42′, without causing any injury to the carriage. In addition to the 6 feet of cover obtained by the carriage and platform, the racer blocks can be set about 10 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 shew himself being pointing, 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 are the wrought iron 64-pounder of 64 cwt., and the 80-pounder converted, firing a 20-lbs. charge.

The radius of the C pivot emplacement, which should always be used with this platform, is 8 feet at top, and 8 feet 6 inches at bottom, having an overhang of 6 inches.

Carriage for $6\frac{1}{2}$ ton gun.—Since writing the above, it has been decided to construct a similar carriage for the 7″ R.M.L. of $6\frac{1}{2}$ tons, and to mount the latter in places approved for the wrought iron 64-pounder.

The radius of the C pivot emplacement for this gun should be 9 feet without any overhang, but perhaps it may be worked in the 64-pounder emplacement.

Colonial carriage.—Several carriages and platforms 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 platform 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 platform 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 platforms.

The design for this mounting was made before that for the 6-foot parapet platform, and it will not be repeated, but it is described here as there are a good many guns mounted in this manner.

Traversing platforms 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 sliding carriages and platforms. 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.—Disappearing carriages are the successors of traversing platforms on the faces of land works. These at present are two in number, the counterweight carriage and the hydro-pneumatic siege carriage, and there are two new ones coming on; one for the 64-pounder R.M.L., or 7-inch R.B.L., and the other for the new 6-in. R.B.L. gun.

Counterweight carriage.—The counterweight carriage of Major Moncrieff's invention is used for the converted 64-pr. 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* VI.); 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 $8\frac{1}{2}$ 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 or open in rear for arcs under 180°, the proportions being slightly different in the two cases.

The drawing (*Plate* VI.) shews 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 not likely to be broken away.

The strength of this construction is considerable, as was shewn at the experiments at Eastbourne, in 1878, when the overhanging part of an experimental counterweight pit was struck by a 64-pr. shot with very little effect; the shot struck, too, at the point where the overhang ended, and where no shoulder had been built to support it, on a corner which, in fact, was quite in the air, which should never be the case in any permanent work.

Few, if any, 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 proposed to construct an improved form. These emplacements are, nevertheless, described as they illustrate a type of construction—the concrete pit with an overhanging wall—which will no doubt continue to be used with altered dimensions for some of the new carriages.

New disappearing carriage.—The new permanent disappearing carriage is not yet determined on. The gun mounted on it will, however, probably fire out of a pit about 12 feet in diameter at the top, which will be safer and less costly than the present counterweight gun pit. The pit will require to be built with an overhang, so as to give room for loading.

Hydro-pneumatic siege disappearing carriage.—The hydro-pneumatic siege disappearing carriage has recently been approved, and it was intended to make permanent emplacements for it in several of our forts (see *Plates* III. and V.), but difficulties have occurred in connection with their design which have not been overcome, and which may result in the production of a new carriage.

It was designed to take the wrought iron 64-pr. R.M.L. gun, firing 12 lbs. of powder, but 25 lb. 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 100 lb. shell, and 25 lbs 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.

This carriage was primarily designed for use in the more advanced batteries of the attack, but it would also be useful in the defence, either in the batteries attached to the forts, or in the forts themselves. In the latter case the advantage would be gained over the permanent disappearing type that the gun and carriage might be kept in a bombproof and only brought out when really required. It must not, however, be supposed that this carriage can be easily moved about, or the gun placed anywhere to fire without preparation. It is heavy, weighing 50 cwt. 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.

Finally, 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 $2\frac{1}{2}$ inches.

Disappearing carriage for 6-inch R.B.L. gun.—The disappearing carriage for the new 6-inch R.B.L. gun will most likely be of a type resembling the H.P. siege, the gun being raised into the firing position by the expansive force of compressed air.

It will probably work a pit very similar in dimensions and construction to the present pit for the counterweight 64-pounder.

It is proposed that it shall be capable either of being mounted in a permanent emplacement with a central pivot, or in a temporary emplacement with a front pivot. It will thus be possible to change the position of the gun during a siege.

Travelling carriage and overbank carriage.—The only modes of mounting for medium guns that remain to be noticed are the ordinary travelling carriage, and the same fitted with a bracket for overbank fire; the 64-pounders only being mounted overbank. On the travelling carriage the gun would fire over a height of 3 feet 3 inches, and with the added bracket it would fire overbank over a height of 5 feet 6 inches.

The 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 under the lower deck and with a long trail plank. The size of the platform is 18 feet by 12 feet. The recoil will be checked by an hydraulic buffer fixed under the carriage and having the piston attached to the parapet.

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. They might also be used in the forts for guns for curved fire, and sometimes for those mounted on the faces for direct fire.

The 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.

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.

The 40-pounder R.M.L. is mounted in casemates on a traversing platform and sliding carriage. It is a good gun for mounting in the flanks of works, in cases when it is probable that men and not earthworks will have to be fired at; for it is sufficiently powerful, and is easy to work.

Special platforms and carriages can be made for these light guns, if there are any particular difficulties connected with the positions in which it is desired to place them.

All the light rifled guns are mounted on travelling carriages, and the 40-pounders and 25-pounders, R.M.L., can fire overbank.

They can be used either in the batteries intermediate between the forts or in the forts themselves. When sufficiently powerful they are preferable to the 64-pounder as being more easily handled.

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.

A modified form of disappearing carriage has been tried for some of these guns in which the gun is raised to the firing position by means of manual labour applied through the medium of an hydraulic press, but it has not yet been adopted into the service.

Rifled Howitzers.

Rifled howitzers.—The old pattern short 8-inch and 6·3-inch howitzers 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 behind the parapet with a good foundation.

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 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°.

The new long 8-inch howitzer of 70-cwt., which will form the greater part of the heavy siege unit, will be mounted on a travelling carriage like the 64-pounder, not overbank, and will in addition have an hydraulic buffer fixed underneath the carriage to be connected with the parapet, so as to check the recoil.

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

Smooth-bore Guns.

Smooth bore guns.—Smooth bore guns, carronades and howitzers, will still be much 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 traversing platforms, 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.

32-*pounder S.B. B.L.*—There is one pattern of S.B. B.L. gun recently introduced for flanking purposes. It is a converted 32-pounder S.B., with an interrupted screw breech closing arrangement, and it will fire case shot only.

It will be 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 9 inches back, or be run in 18 inches more, 3 feet 3 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 6 inches long and 2 feet 3 inches wide, and will 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. 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 8·75 inches above the top of the racer. The racer is a flanged one of the same section as that used for medium guns. The projection of the muzzle beyond the pivot is 4 feet. The height of the sill should be 2 feet 3 inches above the racer.

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.

Mortars.

Mortars.—Mortars, when not replaced by rifled howitzers, 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.

Wall Pieces.

Wall pieces.—Experiments have been made with the 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 advanced by the probable introduction of large single barrelled machine guns, of from 1 inch to 2 inches calibre, which will occupy a position intermediate between the rifle and the field gun, and being at once handy and powerful, are likely to have a considerable effect on the processes of a siege.

Machine Guns.

Machine guns, or mitrailleurs.—The present service machine gun, the old pattern Gatling, is not sufficiently trustworthy in its 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. Under these circumstances it is probable that machine guns will come into more general use.

They will be mounted in two ways; either on tripods, firing over 3 feet 3 inches, or on sockets fixed to walls or baulks of timber.

The tripod mounting would be convenient when using the guns for long range fire, as they could be taken away into some quiet spot where they would not be likely to be disturbed.

The socket mounting would be best when the gun was required to be used on parapets or in casemates. The sockets should be permanently fixed in convenient situations, and the guns put on them when wanted.

Gardner gun.—The Gardner gun, which will probably be adopted into the service, is in three forms, a one-barrel, a two-barrel, and a five-barrel. The latter will be used by the Navy, who want to fire large volleys; it is of different design to the other two. It fires the Martini bullet with a solid cartridge case.

The one-barrel is called a rifle of position; it weighs about 55 lbs. 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.

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 three feet wide for convenience, but can be reduced in width if it is absolutely necessary.

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

In its casemate mounting it is fired through a loophole, which requires a careful description.

Loopholes.—While working on the first design for a fort that I made after leaving Chatham, I wished to introduce a very small musketry caponnier, for the defence of the ditch of a retrenchment; and as there was no room to spare, and every foot was valuable, it was necessary to consider the details carefully, so that no space might be wasted. Of course the length depended on the shape of the loopholes, and on the amount of room required for the men at them, and I thought that these things would be easy enough to find in some book; but no; I suppose that loopholes were looked upon as things of such extreme simplicity, that no one would condescend to record anything about them; I did find something about a horizontal loophole in brick, but I wanted a vertical loophole in stone, so it was not of much assistance to me, and in the end I had to work out the details of the loopholes for myself.

Musketry loopholes.—Plates IX. and X.—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, three 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 1 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 (see *Plates* IX. and X.).

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* X.); a stone or concrete one can be sloped off in the manner shewn in the drawings (*Plate* IX.), 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 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.

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 3 to 4 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 Martini-Henry Rifle is about $1\frac{1}{4}$ inches, and the diameter of an ordinary lead pencil is $\frac{1}{4}$ inch, therefore if you are 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 *materièl* than any other. Rifled guns do not affect it at all. The new explosives, such as gun-cotton can only be used in it to a limited extent. 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 forseen.

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, and they 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 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 distances apart of the branches depend 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 $\frac{1}{10}$ L.L.R.^{3}, their horizontal radius of rupture is $\frac{7}{4}$ L.L.R., and the vertical is $\frac{7}{5}$ L.L.R.

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 L.L.R.^{3} that should be used.

Construction of galleries.—The galleries should be 6 feet high and 3 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, 8 or 9 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 demoralise the storming party than the fear of mines. They should be placed about 10 feet in front of the escarp and 5 or 6 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.

3. 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 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 counter-sloping, 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, $\frac{17}{60}$ 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 $1\frac{1}{2}$ 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 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.

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.

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 fired will be spread over a greater length of face.

As to dimensions, 3 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, as shown in the section of the small fort described in Lecture I., *Plate* V., 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, that, 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 frize* 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 10 feet high to necessitate ladders; with less than that men could help one another up. 15

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, and may be loopholed. There should be a way round 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.

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 6 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 5 feet apart, so as not to offer any facilities for climbing up. On the top horizontal bar spikes must 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.

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 3 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-feet 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 caponnier, 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 caponnier or 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 bomb-proof, and would form a secure shelter from projectiles, of which there is never likely to be too much in a work.

Seven feet 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 also 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 for the men to shift them by hand at all.

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.—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 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.

It will be remembered how carefully in the descriptions of the old systems of fortification all the passages and flights of steps by which the outworks were reached are 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.

At least one covered passage from the rear to the front is necessary for this purpose.

Some of the stairs up to the terreplein should issue under cover of bomb-proofs; there may 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 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 bomb-proof, 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.

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. GATES.

Gates.—The entrance gates of a fortification 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.

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 $\frac{3}{16}$ inch thick at least, and it would probably be advisable to anticipate future improvements in small arms, and to make the plating $\frac{1}{4}$ inch thick.

If iron be used it will have to be about twice as thick.

Framing, &c.—Gates may be framed either in wood or iron. If in the former they should be solid, say 3 inches thick. 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 $\frac{1}{2}$ 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 4 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 6 or 8 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 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.

The bar gate may be made of 1 inch or $\frac{7}{8}$ inch round iron bars, with flat iron horizontal crosspieces 4 feet apart, and diagonals between them.

6. 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 no good 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, and 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 for men to move about in; 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, but besides this the system has the defect that the moments 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 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 I believe.

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 where these chains are fastened 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 counterpoise 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* XI.).

The moveable 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 $5\frac{1}{2}$ 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 $\frac{1}{4}$-inch strips of iron to protect the woodwork.

The inner edge is specially protected by a hinged flap.

To the 9-inch by $5\frac{1}{2}$-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 1 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, as I think these are, 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 3 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 1 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 cut 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 so easily adjusted to the proper weight by variations in the length only of the cylinders. The diameter of the cylinders being 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 weights of materials; there are too many causes of error for one to be right in this way except by accident. The only correct way to get it is to have every part of the bridge weighed in its finished state; all the ironwork as it is complete; 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 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 forms 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 the addition of mechanism is always objectionable.

Fort Regent rolling bridge.—Plate XII.—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. I. shews 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 shewn 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 shewing 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 shew, 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), 400 lbs. 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 $2\frac{1}{2}$-inch iron, is carried into one of the bomb-proof 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 XIII.—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 the one invented by Mr. Guthrie. It to a certain extent partakes of the characteristics of an equilibrium bridge, as in 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, 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 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 strain on the ties that support the centres 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* XIV.—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 the outer edge 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.

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.

A very neat form of swing bridge, for foot passengers only, has recently been designed and put up at one of the batteries at Inch Keith in the Firth of Forth, by Major Locock, R.E., to whom I am indebted for the loan of the drawings.

Inch Keith swing bridge.—Plate XV.—It is 4 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, the levers when up forming 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.

7. FENCES.

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.

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.

8. 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; 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 Serjeants, etc.

Accessory buildings.—The accessory buildings, such as cookhouses, may either be bomb-proof, or be of light construction. On the one hand, it is always advisable to have as much bomb-proof 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 shews 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.

I have in two cases placed them in the counterscarp of the ditch of a retrenchment, where they were secure and handy to the men's rooms, while at the same time they were not liable to become unhealthy.

The roof of a gorge caponnier 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 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 caponniers.—Besides occupying the casemates intended for them, men can be put up in the galleries, gun casemates, flanks and caponniers.

The latter indeed, the flanks and caponniers, 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 there is in a caponnier that I know of.

Some of the old large caponniers 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 caponnier should be a building entirely for warlike purposes. The caponniers of the present day will however be too small for such a use.

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 9 feet between the points of support, and a space of 2 feet wide for each hammock is ample. It should be hung about 4 or 5 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 to this purpose; in a work which was intended to stand alone special provision 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.

The size will depend on the number of the garrison, the allowance per man, and the frequency with which they can be refilled.

10 gallons per head per day is a sufficient quantity. 30 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 should remain so during a siege.

A parapet is not likely to remain of use in that way, but is a good catchwater area in peace time.

LECTURE III.

1. MAGAZINES.

It is best to begin with a few definitions, which are the more necessary as, owing to a change in the mode of storing gunpowder, the nomenclature has been altered within the last few years.

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. Where cartridge and shell stores are combined together in one building, they are collectively spoken of as "Ammunition Stores."

"Store magazines" still retain their old name.

Store magazines.—Main magazines.—Cartridge stores.—Expense cartridge stores.—For convenience of description, magazines may be divided into four classes: store magazines, main magazines in forts, large coast battery cartridge stores, and small expense cartridge stores. There are all sorts of intermediate sizes, but these may be taken as typical. I propose 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 entrance with the shifting accommodation, the magazine chamber, and the lighting.

Shifting Lobby.

Shifting lobby.—Before entering a magazine or cartridge store, every one has at least to change his boots for magazine slippers, and the regular magazine men put on a special suit of clothes.

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 may be about 12 feet square, and 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 accomodation is required, and is often obtained by partitioning off part of a passage.

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 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.

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.

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.

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 an entrance for ammunition also. 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.

MAGAZINE CHAMBER.

The magazine chamber contains the gunpowder either in barrels, metal lined cases, or zinc cylinders.

In barrels it is loose; in metal lined cases either loose, or made up into cartridges for medium and light guns; zinc cylinders contain the cartridges for heavy guns.

The barrels and metal-lined cases are both stored on the same form of skidding; zinc cylinders, as they are very liable to be indented, are stored on shelving.

As the dimensions and the arrangements of a magazine depend on the skidding or shelving, and the mode in which the powder is stored on it, it is necessary first to describe it.

Skidding.—Plate XVI.—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 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.

The bays should be from 10 to 15 feet long in store magazines. In those expense cartridge stores for medium guns, in which the ammunition for more than one nature is stored, it will be found convenient to separate the various natures by vertical divisions.

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, but this rule is not always regarded.

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, and in his 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. I believe that barrels have been stored without injury to a height of 10 rows, but this is probably excessive. Still they might be stored, say 7 rows high without risk, and in a small magazine doing this is preferable to introducing a horizontal transom which might cause a loss of accommodation.

Crane.—Plate XVI.—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. 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.

When there is not sufficient height for the crane a small traveller can be used, running on horizontal bars of wood attached to the uprights of the skidding. It consists of a copper bar supported on two small wheels at each end, and carrying a pulley which can travel from side to side with the barrel suspended to it, and is in fact a minature gantry.

Shelving.—Plate XVIII.—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 as barrels are; but it was soon found that the soft zinc got dented when resting on only the two points of support afforded by the horizontal bars of the skidding; the extraction of the cartridges was thus rendered difficult; therefore it became necessary to support the cylinders in a more continuous manner. This is done by an arrangement of shelving, used instead of skidding.

The shelves are made of 2-inch boards 10 inches wide and about 5 feet long, spaced 2 inches apart. They are supported on 4-inch by 4-inch uprights and cross-pieces, and are made removable, both that they may be taken out of the magazine and aired, and also for convenience in getting at the cylinders stored under them, which rest on the flooring. The shelves, when in position, are prevented from shifting by small pieces of hard wood, $4\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $1\frac{1}{2}$ inches, screwed on to the cross-pieces, and which the corners of the shelves are cut to fit.

The uprights are framed at the feet into cross-pieces and longitudinals, 4 inches by 2 inches, and are further secured to the latter by brass T pieces, 2 inches wide by $\frac{3}{4}$ inch thick, and about 9 inches high and wide.

The spaces between these cross-pieces are filled in with batten flooring, which is described further on, and which is also 2 inches thick, so that a level surface is formed on the floor.

The cartridge cylinders containing pebble powder are stored on their sides like powder barrels, as it is found that, if stored on their ends, the cartridges set up and become difficult to extract, thus causing delay in loading.

Lengths of cylinders.—The lengths of the cartridge cylinders for the charges which are about to be introduced for the service heavy R.M.L. guns, are as follows:—

9″ R.M.L.	10″ R.M.L.	11″ R.M.L.	12″ R.M.L. 25 ton.
75 lbs. P^2	95 lbs. P^2	110 lbs. P^2	114 lbs. P^2
34″·7	35″·3	33″·1	34″·8.

The number which are allowed to be piled on one another, and the heights of the piles, are shewn in *Plate* XVIII.

It will be seen that for R.M.L. guns, from the 9-inch to the 12-inch, the new charges are all about 3 feet long, and the 160 lbs. charge of the 12·5-inch R.M.L., is about 3 feet 4 inches long.

The 210-lbs. charge for the chambered 12·5-inch R.M.L. gun, is about 3 feet 6 inches long.

The shelving for all the smaller natures may therefore be made of three boards, with a total width of 2 feet 10 inches, and for the 12·5-inch gun another board may be added, bringing up the total width to 3 feet 10 inches.

A height for the shelving of 3 feet 6 inches in the clear above the floor is suitable to the 10-inch cartridges, and as it will take all the others it may as well be adhered to in all cases, unless it happen to cause loss of storage.

Charges for new guns.—With the new long guns, the charge is about half the weight of the shot, and the diameter of the chamber, roughly speaking, about one-quarter as large again as the bore. The length of the charge for the 12-inch and for the 10·4-inch R.B.L. guns will probably be between 6 and 7 feet; for the 9·2-inch gun about 4 feet; for the 8-inch gun about 3 feet. The larger charges will be made up in 3 or 4 pieces.

Conversion of skidding into shelving.—Skidding can be converted into efficient shelving by filling in between the floor skids with batten flooring blocked up to the proper level, and by substituting shelves for the upper horizontal bars.

It may be necessary to strengthen the uprights, to compensate for the removal of the horizontal bars.

Wall battens.—Plate XVIII.—Wall battening has to be usedto prevent grit being knocked off the walls by the cylinders. It is made of light 3-inch × $\frac{3}{4}$-inch stuff, and may be made removeable, as shown in the drawing.

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 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 and shell stores, is of two patterns; the stronger one being necessary for shell stores, and the other being suitable for use in all cases where very heavy weights have not to be moved over it.

The stronger one, however, is used in the cartridge stores of heavy guns, the shelving being made to suit it.

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.

Plate XVII.—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 close together, 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 ribbon $1\frac{1}{2}$ inch $\times$ 1 inch is fixed on the side next the wall.

Plate XVIII.—The stronger form of flooring is made of battens 3 inches wide and 2 inches deep, with intervals of $\frac{3}{8}$ inch between each.

The ends are screwed to pieces 4 inches by 1 inch, with $1\frac{3}{4}$-inch brass screws, and a ribbon, 2 inches by $1\frac{3}{4}$ inches, 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, cartridge stores, and shell stores, including the powder and shell passages up to the barriers.

When used with skidding it is placed only in the passages between the bays. When used with cartridge shelving, it covers the spaces under the shelves as well as the passages, and on it the lower tiers of cartridges rest. In shell stores it covers the whole floor.

Magazine chamber.—Having settled the details of the skidding we may now return to the description of the magazine chamber itself.

Store magazine.—Plate XVI.—The most convenient sectional dimensions for a large store magazine will be found to be 19 feet 9 inches 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 6 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.

The length of the blocks of skidding is a matter of indifference, except that it must suit some definite number of barrels, not leaving too much play.

Size of barrels.—A barrel is 1 foot 5 inches in diameter in the widest part, and 1 foot 9 inches long.

A way must of course be left round the ends of the blocks of skidding. In some magazines, which have a central passage running across the chambers, a way may be left through the skidding, the storage being continuous above.

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.

If lifts are used several might be provided, and the passages should be broad.

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 batten flooring, to fort magazines, as they may never be used in peace time, and if the skidding and batten flooring be in them, the wood might perish from damp.

The best course to adopt is to have the woodwork shaped, and stored in some dry place, ready to frame together when required.

If a magazine has plenty of floor space, a number of barrels can be stored without any skidding at all, merely on planks laid down on the floor.

Small cartridge store.—Plate XVII.—Convenient widths for small fort magazines and cartridge stores are 8 feet, 10 feet 9 inches, and 13 feet; 8 feet allows of two rows of skidding and a 3 feet 6 inch passage; 10 feet 9 inches of three rows, and a 4-foot passage; 13 feet of four rows and a 4-foot 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 16 feet 9 inches, or of 15 feet

3 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 19 feet 9 inches.

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.

Coast battery cartridge store.—Plate XVIII.—Coast battery cartridge stores have to be built to suit the cartridge shelving. A chamber with a width of 10 feet will suit all natures of service heavy R.M.L. guns up to the 12-inch, having shelving on both sides of a central passage.

The 12·5-inch R.M.L. gun requires a store at least one foot wider, if complete cartridges are stored on each side of the central passage; as, however, the cartridges for this gun are made up in halves they are easier to arrange than the shorter complete cartridges.

Six feet is the minimum width for a store, with shelving on one side only, for natures up to the 12-inch R.M.L., and 5 feet for the 12·5-inch R.M.L., the latter store taking half-cartridges.

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 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.

Locks.—Brass locks suitable for magazines are specially made; drawings of the various patterns will be found in the Inspector General of Fortification's Circular, No. 190, 16th October, 1871.

(This circular has been cancelled, but the drawings of locks shewn in it still hold good.)

Mantlet doors.—It has been found by experiment, *see* Lecture VII., 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 tubular iron, galvanized, hung on hinges let into the wall, and covered with rope worked over it in form of a mantlet, such as is used about the guns.

The doors should be hung so that they cannot open more than half way, and with a weight attached so that they shall close of themselves.

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.

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 XVII).*

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, has a small reflector and a glass chimney, and burns a candle which is kept in position by being forced up by a spring like a carriage lamp. It will burn for 8 hours. It burns just as well without the chimney, except in a draught, and distributes the light better without the reflector, so that these parts will probably be removed, except that enough chimneys will be issued for use in draughty places. (Since this was written the reflector has been done away with).

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.

Overhead lamps, (see *page* 101).—The overhead lamp is similar to a railway carriage lamp, and is intended to give an overhead light.

It has a projecting rim which rests on the edges of the hole through which the lamp is put. It burns a candle like the wall lamp.

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 to the best of my recollection, the only one that I have ever found it necessary to use, is a square hole cut through the wall, and closed at the end by a pane of glass set in a brass frame. The frame is $1\frac{3}{8}$ inch wide all round; in section T shaped, with a rib $\frac{1}{2}$ inch thick and $\frac{3}{8}$ inch deep. To this rib is secured a flat frame of brass, $\frac{1}{2}$ inch wide and $\frac{1}{8}$ inch thick, the inner dimensions of these two frames being the same, and in the groove thus formed is fitted the indiarubber 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. It is best to have another outer brass frame, with the inner one hinged 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.

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 1 foot 9 inches high by 1 foot 3 inches wide, measured from outside to outside of the rib of the frame. 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 three 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. 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.

The lamp recess fittings are at present under revision.

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.

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.

One is sufficient for an ordinary small expense store; four as a rule are enough for each chamber of a large store magazine, two for the centre passage, one for each side one.

Ammunition passages can be lighted from the ends if there are no bends in them.

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; in a large magazine a little more, not much or there will be a dark space underneath it.

Lamp passages. Lamp passages are usually made 2 feet 3 inches, or 2 feet 6 inches wide, and run round 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. The 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.

If there are many lamps a lamp room is required where they can be kept and cleaned. If the entrance to the lamp passage is a little widened and some shelves put in it, it will do very well. In other cases the lamps are kept in the Artillery store.

For regulations concerning lamps in magazines see the Equipment Regulations for 1881.

2. SHELL STORES.

Shell Stores.—Shell stores are now much more largely required than used to be the case, as it is found that the best place for keeping the powder of bursting charges is in the shells, and all filled shells should be under cover. Accommodation can therefore be usefully provided for the total allowance of shells for the guns in a work.

All projectiles above and including the 7-inch R.M.L. are stored on end; below that size they are piled lying on their sides.

In calculating the floor space required for the different natures of heavy shells, each shell should be taken as standing in a square of a side equal to the diameter of the shell; this allows sufficient room for manipulation.

The requirements of a shell store are similar to those of a cartridge store, but simpler. No skidding is required, but the floor must be covered with boards or batten flooring. The shells will break up any stone or concrete surface, and get gritty so that they become difficult to load with.

Heavy shell may be allowed to cover almost all the floor space, room enough being left to manipulate them and to get at the fuze and tube shelf; they are moved by means of a shell truck something like that used by railway porters.

The rules about shifting rooms and lamp passages for shell stores are a little uncertain; usually they are provided as for cartridge stores—that is, when it is easy to do so; when it is not the amount of precaution is diminished.

It would seem difficult to do much harm to the gunpowder inside a Palliser shell, even with a pair of boots on, and a lantern, but it is well to keep up a certain amount of respect for explosives under all circumstances or they get to be treated too unceremoniously—as witness the miner who is said to make up his charges sitting over the fire by the light of a tallow candle, and a retail dealer who habitually bored holes in the heads of his powder barrels with a red-hot poker; long practice had made him know the depth to which he could safely go, until one day he came across a thinner cask than usual, and the poker went through!

Sufficient care would seem to be taken if a barrier be put at the door.

A lamp passage is convenient, and assists the ventilation, but if it cannot easily be made, the use of a hand magazine lamp is perfectly legitimate.

Of course, if a passage is common both to a cartridge and a shell store, precautions must be taken as for the former.

If there is a want of proper shell store accommodation, and there happens to be spare room, say in the passages of casemated works, the shells may be kept there, but it must not be possible for anyone to unscrew the base plugs and get out the powder. For some 11-inch shell a trial has been made of a sort of grating slipped over them and supported by brackets at about two-thirds of their height; when in position it is padlocked down; this prevents the shells being overturned. It has been reported on favourably.

Fuze and tube shelf.—All shell stores and shell recesses should be provided with fuze and tube shelves, lettered for tubes, and for the various natures of percussion and time fuzes as laid down in I.G.F.'s Circular, No. 204, dated 24th June, 1873.

These should be fixed in some convenient position near the door.

The tubes and fuzes are packed in tin cylinders. The following table* shews the number of fuzes of the kinds mentioned in the above circular 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.		Number the Box will contain.	Remarks.
	Length.	Diameter.		
	"	"		
Tubes, friction, copper, long ...	5·3	2·8	25	
" " " short ...	3·4	2·8	25	
Percussion, Pettman, G.S.	2·3	2·3	5	
R.L. Percussion, Pettman, G.S.	1·7	4·2	5	
Time, 5 sec.	3·9	3·1	5	
Time, 9 sec.	3·9	3·1	5	
Time, 20 sec.	5·5	3·1	5	

* For further information see "Treatise on Ammunition."

Wedge walls.—A shelf for wedge walls is useful, and should be provided when R.M.L. guns are mounted.

Fuze and tube store.—It will in some cases be found convenient to devote a small chamber to the storage of tubes and fuzes.

3. 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 future, in all fort and battery magazines, the powder is to be stored in water-proof 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 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.—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 the foot.

The hollow space here referred to is independent of any air space left behind the lining of the magazine. See page 112.

In a very damp situation it is best to have an air passage in addition to the lamp passage.

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, 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 the 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.

It is desirable not to lay loose stones on the asphalte to form drains as is sometimes done, as 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.

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 under ground 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 that was placed in such a position that the beds of rock sloped down towards it from the parade of the fort, 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 nowadays 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 pretty well 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 of air 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 a good one to make—that no magazine ventilators were to be opened except under the joint recommendation of the O.C.R.A. and the C.R.E.

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 panelled that no shrinkage of the wood will leave any cracks through which burning particles might be able to pass, in the case of a fire anywhere near. Formerly all doors and shutters of magazines used to be 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 of copper wire 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, 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 for 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 passage round the other three. For purposes of ventilation, the entrance passage should be treated as part of the magazine chambers, and the lamp passage separated.

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 mostly 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, 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 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.

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.

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 resource 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 terrepleins 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 the floor of a casemate is sometimes driven across it by the wind, and under the bottom of the doors of the lifts down which it runs into the magazine. A small step about 1 inch high at the top of the lift will stop this. A step is objectionable, but in such a case unavoidable.

For regulations for ventilation of magazines, see *Equipment Regulations*, 1881.

Lining of walls.—The material of which the inner surface of the walls, arches, and floor is composed is 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.

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 $4\frac{1}{2}$ 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 than 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 nonconducting 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, gets beaded with moisture if there is any quantity in the air; this can be remedied by covering it with cork composition as it is called, 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 capital stuff 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 floor and metal work.

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.

4. MAGAZINE ACCESSORIES.

Having now described the magazines themselves, the lifts for removing the ammunition remain to be noticed, and also some accessory buildings.

Lifts.

Lifts for heavy guns.—Plate XIX.—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.

They are usually circular in plan and 18 inches in diameter, though the lifts for the larger heavy guns are best made 1 foot 9 inches in diameter, and general lifts, used for powder barrels as well as for cartridge cylinders, are made square with a side of 2 feet 3 inches so that a barrel may be lowered with the axis horizontal.

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, though if a projected increase in the charges is carried out, crabs will have to be fitted to the lifts of all guns that fire larger charges than the 10-inch R.M.L. of 18 tons.

The cartridge lifts for all the new R.B.L. guns larger than the 8-inch of 11½ tons will require crabs.

All shell lifts for heavy guns are provided with crabs.

Lifts may be made in the walls or arches of ammunition stores, and may issue in the floors or walls of casemates, or bombproofs, or in the rear revetments of the traverses of barbette batteries.

The best place for them 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 7 feet, and should be carried down to the floor level.

In the battery the top of the lift should be at least 7 feet above the floor, and may with advantage be a foot 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, the overhead block, &c., to allow for.

Plate XIX.—The drawings shew 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 shewn.

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.

New patterns of shell and cartridge crabs are in course of preparation. It is, therefore, no good to give descriptions of those now in use.

Safety trap for cartridge lifts.—This contrivance is not shewn in the drawing, being of later date, but it should be applied to all new cartridge lifts. It is one of the results of the experiments carried out at Eastbourne, and described in Lecture VII., and is intended to prevent the effect of any explosion on the gun floor or in the top of the lift passing down into the magazine.

It 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 accomodate 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.

Widening top of 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 6 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 $16\frac{3}{4}$ inches by $16\frac{3}{4}$ inches by $20\frac{5}{8}$ inches. The lift had better be 1 foot 9 inches in diameter and should be provided with a ring bolt 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.

Davit.—It is occasionally convenient to hoist ammunition up by the rear of the rampart. In that case a davit can be used, made of $2\frac{1}{2}$ inch round iron, pivoted and having an overhang of 3 feet 2 inches, and with an eye at the end to take the hook of a block.

Recesses.

Ammunition recesses.—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 two forms will here be described, one suited for the use of heavy guns, the other for medium or light ones.

Recesses for medium guns.—The recess for medium gun ammunition, whether for shell or cartridge, may be made 3 feet wide, 2 feet 2 inches deep, and 3 feet 9 inches high.

This will contain 23 64-pounder or 7-inch 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.

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 should 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 by $\frac{1}{2}$-inch iron, the latter should consist of bolts at top and bottom and a swing bar in the middle of $2\frac{1}{2}$-inch by $\frac{1}{2}$-inch iron, secured by a padlock. Hooks should be provided to hold the doors open in a wind.

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 4 feet wide, 3 feet 6 inches deep, and 5 feet high. This will take 14—10-inch cartridges or 12—10-inch shells.

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.

LABORATORIES.

Laboratories.—Laboratories are buildings in which cartridges are made up and shells filled. They are of a light construction so that as little injury as possible may result from an explosion taking place inside one of them.

All the laboratory operations can be carried on in a tent, but as they are numerous and frequent it is advisable to have permanent buildings for the purpose, and a suitable one is shewn on the lithograph accompanying I.G.F.'s circular, No. 226, dated 2nd June, 1875.

The whole building internally is 17 feet by 20 feet 9 inches. It contains an entrance lobby fitted for shifting clothes and a room for working in, which is provided on one side with two benches for filling cartridges at, one with drawers and one without, a weighing bench rather lower than the others, and some small shelves, and on the other side with some skidding to hold empty cartridge cylinders.

Let into the floor are two oak blocks with conical holes in them, and fixed to the roof over them are two ring-bolts. These are for up-ending Palliser shell which are filled through the base.

There is an issue hatch in the wall at the floor level 2 feet 6 inches high and 3 feet wide, with a sliding door, and near it a shelf for the paint for marking shell.

Some lamp recesses are arranged to light the benches if work has to be carried on at night, the lamps of course being inserted from the exterior.

The powder and shell to be used are brought in by the lobby and passed out by the issuer.

The arrangements shewn on the lithograph are not intended to be absolutely binding, as of course sometimes the exigencies of the site may compel some variation, but they are convenient and include all that is wanted.

With regard to the positions in which laboratories should be placed there is a regulation that they should not be within 40 yards of a magazine.

This it is almost impossible to keep to on account of the limited areas of forts, and it is recognized that a solid traverse between the laboratory and the magazine is a sufficient protection.

With regard to the number and arrangement of laboratories it is to be observed that all the cartridges and shell used in a fortress are made up and filled in the laboratories; there is thus a great deal of work done in them, and although they can be supplemented by tents if there is a great pressure, yet several are evidently required in a large fortress.

It is difficult to lay down any precise rule for their number, but any very large coast battery should have one; a group of small batteries might have one between them, and three or four land works might also share a laboratory between them.

Their position should be chosen so that the powder from the main magazines and the empty shells from wherever they are stored, may be conveniently taken to them to be made up into cartridges and filled shell on the way to the batteries.

This is a matter to be arranged with the Artillery and the Ordnance Store Department.

For regulations concerning laboratories in charge of Royal Artillery see Equipment Regulations, 1881.

Adjuncts to Store Magazines.

Examining room and cooperage.—As the Ordance 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 traversed from it; 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.

Empty barrel store.—The subject of storage in magazines may be completed by saying that in large magazine establishments, in addition to the above, an empty barrel store and a magazine store for wadmiltilts and such articles are required.

Nomenclature.—*Lettering.*—Finally the proper "Nomenclature of Artillery Magazines and Stores" may be found laid down in the Equipment Regulations of 1881, and the mode of "Lettering Emplacements and Accessories to Works of Defence" is defined in Clause 141, *Army Circulars*, September, 1877.

LECTURE IV.

1. COAST DEFENCE.

THERE are three classes of weapons with which ships can be fought from the land—guns, submarine mines, and locomotive torpedoes. The latter are not yet in use in our service. Besides costliness, their great defect is want of range.

The system of defence of a place is not 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 shew 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, while the submarine mine may not be laid in time, or may be affected by storms and currents.

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. Fresh mines can 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.

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.

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, however, going into the details of the batteries, and the choice of positions, it would be well to say a few words on the nature of the guns used, and of the ships that may have to be fought against.

Guns.—Table of Guns and Armour.—The first part of the Table (see *Table* at end) shews the guns which are at present mounted in English coast batteries, with their approximate penetrative power against wrought iron plates at various ranges, and it also gives the same information for the new B.L. guns which are being tried, and which will probably supersede the older short M.L. guns.

These B.L. guns are still in the experimental stage, and very likely their proportions will undergo some modification before they are finally adopted into the service. Already, indeed, the 6-inch gun can be credited with a 100-lb. shot and at least one inch more penetration than is shown for it in the Table. The essential difference between these new type guns and the old ones is, that they 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.

A further reference will be made to the guns after having spoken about the ships, their armament and armour.

Ships.

List of armoured ships of the world.—In the "Journal of the Royal United Service Institution" for July, 1880, will be found a complete list of the armoured ships of the world, except the English, giving their size, speed, thickest and thinnest armour, their armament, and other particulars. This is the first such list that has been published in this country, and it must be admitted that it is not very creditable to ourselves, as a naval nation, that we have been for many years behind the French and Austrians in this matter.

The Austrians publish a list annually in the Marine Almanac, and the French also in the "Carnet de l'Officier de Marine." King's "War Ships of Europe" and Very's "Navies of the World" are good works on this subject, and there are others besides them.

Draught of water.—In the Austrian Almanac will be found the draught of water of the ships; this was omitted from the table in the Journal of the United Service Institution on the grounds, I believe, that it was not a fixed quantity (as of course the draught of water depends partly on the amount of stores on board and the trim of the ship) and that it was not a matter of much interest to the Navy, whose fighting would be mostly done on the open sea, but it is of importance to us as giving us some guide when laying out the defences of a harbour or channel, as to the area of water to be commanded by the heavy guns.

A ship must not have the chance of creeping in over some shoal water, and of attacking the batteries from a position where she cannot be replied to.

Most ironclads are large vessels that could not venture into water less than 5 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; and there are two very powerful turret ships, the *Solimoës* and *Javary*, belonging to Brazil, which draw less than 12 feet.

Classification of ships of war.—War ships may be classified for our purposes in the following manner:—

Unarmoured ships.
Third class armoured ships.
Second class ,, ,,
First class ,, ,,

and a few exceptional ships, viz., four Italian vessels, one English and three French, the number of which is not likely to be largely added to, for the English Admiralty have announced that they do not believe in them, and the Italians are beginning to hesitate in carrying out their idea of having immensely powerful vessels, and, it is said, do not intend, at any rate for the present, to lay down any more.

The three French ships will carry their guns *en barbette*, and are not suited for attacking land works, for which purpose the French build special vessels.

Table of Guns and Armour.—The second part of the Table (see *Table* at end) shews the armoured ships approximately classified together, being arranged according to the strength to resist shot at their strongest part.

The first part of the Table shows the guns which will penetrate them at various ranges, but it should be observed that, as almost all ironclads carry armour of various thicknesses, the ships of any class can be injured by less powerful guns than those set against them in the Table; but the less powerful guns will not penetrate them at their strongest part.

Third class armoured ships.—The third-class vessels include all the old ironclads which were first constructed, and a number of light turret ships, mostly belonging to Russia. They may be taken as those with protection which is equivalent to less than 9 inches of iron, and include about one-half of the whole list. The classification is somewhat arbitrary but is convenient.

The turret ships are hardly capable of going to sea, but most of the others are efficient cruisers, and as they are no longer capable of taking their place in line of battle, they will probably be relegated to the work of protecting the commerce of the nation that owns them, and of attacking the commerce of its enemies.

Some of them also may find their way into the hands of the smaller Powers, who will get them cheap from the large ones, the latter disposing of them as costing as much to keep up as new and more powerful vessels of the same size; or they may even fall into the hands of privateers.

As the result of these causes we must expect to find lightly armoured vessels all over the world in the hands of all sorts of people, and employed in all sorts of services; and among other services will doubtless be that of attacking any of the enemy's ports that may promise a fair return for the risk, either in tactical advantages or in plunder. Consequently, in considering the defence of harbours of any but the smallest class, we must be prepared to deal with light ironclads.

Second class armoured ships.—The second-class ironclads, or those whose protection is equal to from 9 to $10\frac{1}{2}$ inches of iron and which include about a quarter of the whole list, form a much more important class, which is not at all likely to drop out of use in the navies of the world. They will be employed in war time, as they are in peace, in a great variety of services, but mostly on the open sea. They will be too useful to be risked in attacking a place of small value; but such important points as our coaling stations at the Cape, Hong Kong, or Singapore should certainly be prepared to beat off such vessels. Nearly all the nations which possess any navy have one or more of the second-class ironclads.

First class armoured ships.—The first-class ironclad is the line-of-battle ship of the present day, and forms a type only possessed by the Great Powers. At the beginning of a war these would certainly be kept for fleet actions, as no other naval operations could be undertaken by any Power until a superiority at sea was obtained.

This might be only a local superiority, of course, but it would set free the enemy's fleet for further operations in those waters.

For example—with our widely scattered interests it is quite conceivable that our Mediterranean fleet might be overpowered, or at least much injured, and that, we not being able to reinforce it, our enemies might commence a formidable attack on Malta, to carry out which their first-class vessels would of necessity be used, none others being powerful enough.

It is, however, a point worthy of notice, that many of these ironclads are not suited for attacking coast batteries, at least at close quarters, and are not intended to be used in that way; these are the ships with their guns *en barbette*, a system of mounting them which has been largely used by the French and Germans, and which is about to be introduced into our own navy. Ships carrying their guns in this manner are intended for naval actions only, but the French have built special coast-defence ships which would do very well for coast-attack ships; these supply the deficiency of their sea-going vessels, and would no doubt be used in any naval operations against powerful coast works.

Moreover, it must not be forgotten that for the attack of a great naval fortress, defended by all the resources of modern warfare, great efforts would have to be made, and, without doubt, special battering ships would be constructed, designed to resist the heaviest artillery mounted on the works.

Exceptional ships.—The exceptional vessels would be used under the same conditions as the first-class ironclads.

There are only eight of these vessels at present in hand; of these, five will most probably have their guns mounted *en barbette*, *i.e.*, the *Amiral Duperré* and her sisters, and the *Italia* and *Lepanto*.

Unarmoured ships.—The unarmoured ships form a crowd of vessels of all sizes and armaments.

The larger ones carry as a rule more guns than armoured vessels of the same size, but these of a less calibre.

Somewhat curiously the smallest of all carry the heaviest guns, such as the *Comet* class in the English fleet, carrying 10-inch 18-ton guns, and the Chinese gunboats which carry guns from 18 tons to 35 tons weight.

These vessels can, of course, all be pierced even by the lightest rifled guns at any reasonable range. Their draught of water varies very much, some being especially designed to act in shoal water and in tortuous channels.

The Nature of a Naval Attack.

Naval attack on forts.—It is equally necessary, in order that coast defences may be properly designed, 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 case under consideration.

Want of modern experience.—But in the consideration of questions of naval war we labour under a disadvantage from which we are to a great extent free in the case of operations on land, for we have very little modern experience to guide us.

The great continental wars of the last fifteen years have supplied us with such an amount of information on the employment of modern weapons, that though there are doubtful points still left, yet we know enough to be able to design our works with considerable confidence as to their suitability to the conditions of warfare.

But with naval warfare it is very different. The accounts of the American Civil War are still almost the only ones to which we can 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 Randolph's paper on "Naval Operations during the Civil War in the United States," in the "Journal of the Royal United Service Institution," No. XCVI., 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.

In the "Journal of the Royal United Service Institution," No. XCII., 1881, is an account of the Naval operations in the Chili-Peruvian war, by Lieut. Madan, R.N., which is also well worth reading.

On land—the Engineers attack.—But there is another great difference between land and sea attacks. 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 whole question lies 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 may safely say that I have never 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; as to anchoring, or keeping on the move by circling, that would depend on local circumstances, but fighting on the move is preferable.

Now 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.

For myself, 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 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.

Naval Attack and the Guns of the Defence.

Naval attack upon a small place.—The naval attack on a small fortified place and on a large fortress would naturally differ in details. The attack on a small place would be made with whatever ships might happen to be available; they would come as close in as they could; any ironclads that there were might possibly anchor, the unarmoured vessels would circle; the work would be very hot while it lasted, but could hardly be kept up for long. An attack by a single ship is very unlikely to be made, except against a small or weakly protected place for the purpose of plunder. In designing a battery it should always be looked upon as likely to be fighting at least two or three ships at a time.

Naval attack upon a large place.—The attack on a large place, like Portsmouth, would be a matter of elaborate preparation.

Special armoured vessels would be built, and very heavy guns sent to sea.

Owing to the number of guns mounted, it would be almost impossible to silence them rapidly, and efforts would therefore be made to ruin the works.

Small gunboats with heavy guns firing from a distance would be one of the means used for this purpose, as it would be a way of bringing a heavy fire to bear at a comparatively small cost or risk.

During the progress of the attack, all sorts of efforts would be made to remove the obstructions and mines, and to injure the works by explosion ships and such means, which with modern explosives (other than gunpowder) might prove very effectual against forts rising immediately out of the water.

In fact, the whole affair would somewhat resemble a siege on land, and it would call for great energy and resource in securing the defences, in repairing injuries, and in devising modes of meeting the enemy. Many of the latter, such as the use of torpedo boats and of armoured vessels on the side of the defence, would form part of the duties of a naval contingent. Indeed, a successful defence could hardly be made without such a force; it would be like defending a fortress against a land attack without any moveable artillery.

Power of guns required.—From a consideration of the facts given above, and of the classification of the ships, we may deduce some rules for guidance in determining the power of the guns necessary to use in any particular case.

Guns for a large European fortress.—For a large fortress in European waters, the only safe rule to follow is to mount the heaviest guns you can get, and as many of them as you are likely to have men to work, for, as we have seen, such a fortress would not be attacked at all, except by a powerful fleet, containing vessels specially constructed for such work, and very possibly built with a view to the attack of that very place.

Constant improvements necessary.—It is therefore necessary to make careful preparations, and to be constantly improving the works, so as to ensure their not becoming antiquated.

To do this properly, it is essential to follow the progress of naval architecture, and of artillery, not in their details of course, but to such an extent as to be aware of what guns might be brought against the works, and their powers of penetration, so that steps may be taken to keep the casemates and magazines, etc., in security; and also to know the thickness of armour which might be carried by the vessels of the attack, so that the power of the guns of the defence may not fall behindhand.

The attack on second-class fortresses—Class of vessel likely to be used.—Less important places are not liable to have attacks upon them arranged in such an elaborate and costly method as the first-class fortresses, unless some accident of the war should render their possession a matter of much moment to the enemy, but an exceptional state of things like that cannot be provided against beforehand; we can only consider probabilities, not possibilities, in devising schemes of defence, or the preparations would overweight us, and we should be as weak as before, though from another cause. Such an attack would have to be encountered by the fleet.

What then is the form of attack which might be expected to be made against a fortified harbour of the second-class, and what ships would be used?

This would depend to a great extent on its position, for we may assume that no Power would go very much out of its way to attack such a place.

For unless a Power had the intention of annexing one of our Colonies, and sent a large force for this purpose—when the case becomes an exceptional one to be met by exceptional means—the only object of attacking one of our smaller fortified posts would be to interfere with the commerce passing that spot, and the result, if success were attained, would not be sufficiently great to warrant the employment of large means to attain it. For the capture of the most important coaling-station and commercial harbour would certainly divert the traffic to another route, and would probably increase the difficulty of guarding it, but would not necessarily destroy it.

The probable nature of the attack then on such a place would depend on the nature of the ships that the enemy might have to spare from his main operations, and, as it would be easier to spare them for a short time than for a long one, the nearer the place is to the enemy's base of operation the more severe the attack is likely to be.

Those places which are distant from the possessions of all nations having large navies are not liable to molestation, except from the ships of flying squadrons, any ironclads included in which would of necessity be masted and fitted for cruising, and up to the present there are few first-class ironclads so rigged; the few that there are would probably not be sent wandering over the world, but be kept near home for more important duties than burning coal depôts and capturing merchant ships.

Second-class ironclads likely to be employed in the attack of coaling-stations.—There are a large number of second-class rigged ironclads, however, and these might turn up almost anywhere, and this fact fixes the minimum power that should be given to the guns to be used for the defence of the coaling-stations and large commercial harbours.

Guns for the defence of coaling-stations.—It will be seen from the Table of Guns and Armour, that the second-class ironclad may be considered to be one carrying armour and backing equal to a thickness of about $10\frac{1}{2}$ inches of iron, and that this is penetrable at 2,000 yards range by the 10-inch R.M.L. gun of 18 tons; this then we may consider as the ordinary coaling-station gun; it fulfils all the conditions remarkably well, being sufficiently powerful, and at the same time simple in construction and mode of mounting, and easy to handle.

Since writing the above, two considerations have acquired such weight as somewhat to disturb the opinion just given in favour of the 10-inch R.M.L. gun. One is that the rapid improvement of machine guns has rendered the service of muzzle loading guns in casemates increasingly dangerous, so that it is a question whether it is right to mount any more in that manner. In *barbette* batteries it is to be hoped that we shall get over the difficulty by under-cover loading, some experimental forms of which are described in a later lecture.

The other is that the accuracy of the new type guns, and the long ranges commanded by them, will enable them to be used at distances at which our guns, with the elevation allowed by the carriages on which they are mounted, cannot reply. The new guns will range about half as far again at the same elevation as old ones of the same calibre. Therefore, when batteries fire over the open sea, or down long channels, either new-type armour piercing guns must be mounted, or, the the short armour piercing guns, such as the 10-inch R.M.L., must have other guns associated with them for long range fire. The first method will, of course, be effectual; whether the second will be so remains to be proved, but there would be several advantages attending it, one being that comparatively light guns, such as the 7-inch or 8-inch, might be used for the auxiliary armament, since these would be powerful enough for attacking unarmoured ships and the decks of ironclads at long ranges, while the heavy guns would be reserved for more serious work.

In any case, with armour-piercing guns, other lighter guns should be provided for various purposes, such as firing at unarmoured ships, and at boats, and preventing landings being made.

Guns for places near hostile territory.—Places, however, which are near the territory of a hostile Power are liable to a much more severe kind of attack than this, as it may become possible to detach against them some of those so-called coast-defence turret ships which some of the Great Powers possess. The armouring of these may be equal to that of a first class sea going ship, and guns capable of penetrating them must be provided. To know what guns are necessary one must watch the progress of a possible enemy, learn what ships he has built, divine, as far as one can, what he is going to build, and act accordingly. Luckily nations copy from one another a good deal, and ships take a long time in building, so that the direction that progress is likely to take can usually be pretty accurately judged for some time beforehand.

In some places it may be advisable to mount heavier guns than would naturally be required, for the purpose of obtaining some special result, such for instance as that of keeping the enemy at a distance and so preventing a bombardment. Such cases must be judged on their merits, but it must always be remembered that the very heavy guns require too much skill and care in their management to be intrusted to any but trained men. The 18-ton R.M.L. gun is the largest that can be easily manipulated, and a heavier and more complicated machine should not be used unless there is a certainty of ensuring proper superintendence.

Defence of small commercial ports.—There is a third class of harbour which has not much cause to anticipate a visit even from second-class ironclads, namely the small commercial ports from which an enemy could get nothing but a small ransom, which would not be sufficient to set against the possible loss of an ironclad—a loss which in war time would not be measurable by its money value.

Against such harbours then a good ironclad would not be sent, as she might be blown up by a submarine mine, or a torpedo boat might make a lucky dash at her; but they might get a visit from a cruiser, and among this class, as we have seen, we shall have in future to include the old lightly armoured ironclads.

Guns for small harbours.—The guns, therefore, for the protection of such ports should be capable of piercing, say, 7 inches of unbacked iron at 2,000 yards, for the better third-class ironclads would be too valuable to send against them. This can be done by the 9-inch R.M.L. gun, which would be suitable for such a purpose so far as power is concerned. The gun, however, is not altogether fit for such a use, as it is heavier and therefore more expensive than is now found to be necessary, and it requires an emplacement almost as costly as that for the 10-inch gun.

The proposed 6-inch R.B.L. gun, with its original charge, did not keep up its penetrative power sufficiently well at long ranges to be adopted as a satisfactory substitute, but it will be improved in that respect, and may then become suitable. The mode of mounting it has yet to be decided on.

The 7-inch R.M.L. of 7 tons, and the 64-pounder R.M.L. wrought iron gun have both sufficient penetrative power to warrant their firing at a light ironclad with a fair probability of inflicting injuries, though not with the certainty of doing so, except at short ranges.

The latter gun, the 64-pounder, is the best mounted gun in the service for coast defence work, as it can be worked entirely under cover of the parapet, and it is now intended to mount the 7-inch $6\frac{1}{2}$-ton gun in a similar manner. (See Lecture II., p. 53.) These will be fairly powerful weapons, which it will be extremely difficult to silence.

If the visit of an ironclad be put out of the question, then, for use against unarmoured vessels, the 64-pounder is a very good gun. Large numbers of these are mounted, mostly converted from cast iron guns on Palliser's system. Of course protection against an ironclad may be obtained in this case by the use of submarine mines.

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'étre* 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 few days against any attack which may be reasonably expected to be made; otherwise it is not much good fortifying the place at all.

2. EFFECT OF PROJECTILES.

Before describing the various forms of gun emplacements and batteries, it is advisable to say a few words on the effect of heavy shot and shell on iron, masonry, earth, and other materials. It is to be regretted that a few words is all that it is possible to say on the subject, for our information is by no means so complete as might be wished. We must, I suppose, wait for a big war for experiments on a grand scale.

In the meantime we much require a trial of the effect on masonry of the projectiles from very large guns, such as the 80-ton R.M.L.

(Since writing the above such a trial has been decided on, and preparations for it are being made).

Penetration into iron.—Penetration into iron constructions is dealt with by Colonel Inglis in various recent articles in the *R.E. Professional Papers*, more especially in that published in July, 1880, which also treats of the new type of guns which are now being introduced into use by all nations.

The "Notes of Lectures on Iron Fortifications," delivered at Chatham, in February, 1875, form a summary of information up to that date.

A book which treats fully of our works, and which is very well illustrated, is the *Küstenbefestigungen Englands*, by Küster, published at Berlin in 1873, at the Publishing Establishment of the Engineer Committee; but it probably cannot be procured through a bookseller.

I shall, therefore, say nothing on this subject, except to give a rule for estimating the power of a gun, which is approximately correct and easily remembered; it is, that, against wrought iron plates, 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 fourth to its thickness will give the thickness of a wrought iron plate of equal strength to resist a single blow. The steel-faced plate would, however, break up sooner than the wrought iron one under repeated blows from steel shot.

Displacement of shields.—As affecting the masonry construction, however, one effect of a shield being struck by a heavy projectile may be mentioned, which is that there is a tendency for it to be moved back bodily, and this must be resisted by the disposition of the stonework 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* XX. If an iron roof be used the girders hold the top of the shield in place, and their rear ends should, if it be possible, be abutted against some solid building such as the end of a casemate. See *Plate* XXI.

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.

Penetration into masonry: Shoeburyness experiments in 1865.—The principal information that we have concerning the penetration of heavy projectiles into masonry is 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 shewn in *Plate* XX.

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 very instructive.

Effect of firing against centre pier.—A 9-inch steel shot fired at the centre pier penetrated 9 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 twenty-two blows, twelve 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 ten 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 similar guns to these used would now hit much harder at these ranges, and the effects would consequently be greater.

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 130 lbs. P., the striking velocity of the projectile about 1,405 feet per second.

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.

Results obtained from the Civil War in America.—A little definite information on this subject can be got from the American Civil War.

During the bombardment of Fort Sumter a shot from a 10-inch rifled gun struck a pier (8 feet by 5 feet in plan) diagonally, and carried it all away except 18 inches of one corner. There was only one 10-inch rifled gun mounted to fire at Sumter, and it was 4,290 yards distant.

It fired a shot of 300 lbs. with a 26-lb. charge, and the energy was certainly far inferior to that of shot of the same calibre of the present day.

It was found that 8-inch rifle shell, fired at ranges of about 2,500 yards could penetrate a 5-feet brick wall. If they struck a wall thicker than 5 feet they only penetrated 4 feet into it.

Deductions.—These are all the experiments we have with heavy guns against masonry structures.

They appear to shew the value of a hard exterior such as granite in bringing up a shot; and that, while the actual penetrations are not very great, the disrupting effect is very considerable; this can only be met by mass and tenacity of material.

Good Portland cement alone should be used in the construction of works intended to resist artillery, never inferior cements or mortar. Hoop iron bond might be advantageous, but it is a question whether it might not tend to cause cracks instead of preventing them.

An inner skin of iron would help to check the disturbance of the masonry, and would probably add considerably to the strength of a casemated work such as was tried at Shoeburyness. An arrangement of this nature has lately been applied to some shielded batteries.

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 gun gave a mean penetration for 23 shots of $36\frac{1}{2}$ feet; the maximum penetration was 50 feet.

A 9·22-inch 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 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.

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. Experiments are being made with a view to obtaining 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; and also to fire steel shell filled with guncotton. If these investigations are successful the effect of shells will be much increased.

Dungeness in 1880.—The experiments at Dungeness have shewn that the effect of an 8-inch shell against concrete and brickwork is very great, even when thrown with a low velocity.

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 shrapnel.—Against open batteries ships would fire shrapnel wth 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 and a good time fuze combined, and the conditions are difficult to realize 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.

Case shot.—Case shot is not likely to be fired against batteries, as it is, as a rule, only effective up to 300 yards. Good results have, however, been obtained from the long 8-inch B.L. gun with case shot at 600 yards. If a favourable opportunity were to occur though it would doubtless be used.

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 be certainly used against batteries as long as they could be worked, which might not be long, for they are in no case mounted behind armour. Against barbette batteries they might be very effective from the rapidity of their fire compared with that of the heavy guns.

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.

Machine guns.—The use of machine guns, as mitrailleurs are now called, is rapidly spreading in all navies; the smaller sizes are intended for firing at ships' decks or into their ports, the larger ones for repelling torpedo boats.

Small machine guns.—The smaller ones are numerous in pattern; they usually fire an infantry rifle cartridge, and when accurately laid are comparable in the effect they produce to a number of men firing rapidly.

Heavy machine guns.—The larger kinds are represented by the Hotchkiss in the French navy and by the Nordenfelt in our own. The former is a revolving gun of $1\frac{1}{2}$-inch bore and can fire a shell. The latter is a volley gun firing four shots at a time; it is of 1-inch bore and uses a steel shot.

They can penetrate a $\frac{3}{4}$-inch steel plate at 200 yards range.

The force of the shot 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.

This class of weapon, which is a new one, will, there is no doubt, be shortly considerably developed.

A $1\frac{1}{2}$-inch gun of Nordenfelt's has been tried that will penetrate 3 inches of iron plate, or 2 inches of steel, at the muzzle, and larger guns are proposed.

As to rapidity, the Nordenfelt will give 100 aimed shot per minute, the Hotchkiss about 30; the proposed heavier guns probably about 20 shot a minute.

As to accuracy, it is considered that experiments have shewn 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 3 feet out of water, with 7 feet 6 inches beam; when this can be constantly hit while in motion we may be sure that forts would get many bullets in the ports and about the guns.

Machine guns are perhaps the most dangerous enemies we have to contend with; it might be quite possible for a boat armed with a machine gun to keep a heavy gun silent, that is, if the boat could manage to begin, which it might be able to do in the confusion of an engagement.

The effect of the Hotchkiss shells against men has been shewn to be considerable, in actual warfare.

In addition to all these the crews of ships of course have rifles.

LECTURE V.

1. 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.

On the principle of having two strings to one's bow, it is advisable to combine these two methods as far as possible, *i.e.*, a good torpedo line should be chosen, 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.

The precautions against close attack are the same for all 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.

If you can place your works 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 and 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. The batteries, however, might be still of much use if the ships were away, as they should prevent the enemy's vessels 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.

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.

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 field, 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 ships' 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, consequently each gun will have the opportunity of firing many rounds; to have a number of guns, in order to produce a great momentary effect, is, therefore, not required.

This condition demands either heavy traverses or casemates, and indeed, properly, casemates should always be used.

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 primary 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 reviewing these cases in detail, and 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 rare, 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 it 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.

2. 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, and 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 and 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 get their approaches defended by a long string of works.

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 directly 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.

The position of the second line should be chosen on the same principles as the first line, and should 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.

Very small places.—In very small places there may be no question of second lines or even of interior works.

There may be half a dozen heavy guns or less 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 casemated guns would make it very difficult to force an entrance; for the enemy could not silence the guns without getting in front of them, and when there, his ships would not be able to manœuvre freely for fear of the mines, so that the defenders would have a good chance. It would be worth while arranging the guns this way, even if none were left for preventing a bombardment, for no great injury can be done if the place is not captured. Of course, it would be always possible and well worth while in such a case, to mount some medium guns to fire to seaward; they would at least keep off unarmoured ships and might even incommode an ironclad.

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, and if the channel is blocked at such a distance off, that the enemy must pass the works in order to get within range of the town, this further end is thus attained.

But it is often the case that it is not so. The distances at which a town can be bombarded may be taken at 10,000 yards, or about six miles. The shooting 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 new 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 is well to divide the guns at least partially and arrange them so that while some fire to seaward others shall fire only on the channel, and shall be so protected that the enemy shall not be able to silence them until he comes within the area of their influence, and tries, as he probably would, to enter the place.

Bombardment cannot do much harm.—For 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 one thing in a dockyard that can be seriously injured by distant shell fire is machinery, unless indeed it contains ships undergoing repair. Machinery might in some cases be protected by bomb-proof cover. I know of no reason, except the cost, why this bomb-proof cover should not be built in peace time, as well as the forts, but as a matter of fact I believe 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; thus in the case of Otago, New Zealand, the harbour has a bar entrance which is easy to defend, and it is about 12 miles long; but the upper end of it where the town stands is only separated from the sea by a strip of sand 1,000 yards wide. It is consequently necessary to place a battery here to protect the town from bombardment.

The best style of battery for keeping ships at a distance is a barbette battery if tolerably high ground can be got for a site. The help that the guns give one another, owing to the large arc of fire that it is possible to give them with this kind of mounting, 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 is usually advisable 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. This suggestion, however, like many others in fortification, is easier to give than to act on everywhere; as a matter of fact one of the heaviest armoured batteries that we have in England, the Breakwater fort at Plymouth, was intended merely to prevent a bombardment of the ships lying in the Sound.

Indeed, whatever theories may be laid down about coast batteries, their character mainly depends on the ground, on the number and character of the garrison, and on the money available with which to build them.

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.

In the defence of first-class ports, such as Portsmouth, it is not worth while to make any arrangements for firing on to 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 in which the harbour itself is the important thing, and the loss of all the stores in it a comparatively trifling matter so that the place itself be not abandoned, it is a good precaution to have a few well protected heavy guns 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 should 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.

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 may also have to be arranged to fire on the entrance; but if one or two can be devoted entirely to the reserved defence, and so mounted as to be unassailable from the exterior, the defence is made very much stronger; the enemy's ships would have to make two distinct attacks, the second following immediately after the first; the vessels would be obliged to operate in the harbour, probably a confined space where their powers of manœuvring would be much restricted; and all the ranges should be known to the garrison.

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 unseen from the exterior, as 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.

The work in which these guns are mounted will require protection from the attack of ships from the outside, but this may often be obtained by massive construction without its being necessary to provide heavy artillery on the seaward faces.

The guns used in these works 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 usually renders it necessary to casemate at least some of the guns, in order to shelter them from the accurate curved fire of the present day.

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 Madalena.*—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, and it seems essential to provide the guns with casemated cover.

No amount of height in the traverses will make the guns safe against curved fire.

It is desirable to place such a battery 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.

Arrangement of Subject.

Having now considered the objects of coast defences and the mode of using them, I propose to consider the batteries in more detail, beginning with the carriages and platforms of the guns and going on to describe casemate and barbette emplacements.

3. MODES OF MOUNTING GUNS.

Platforms.—All heavy R.M.L. guns in the service, from the 7-inch of $6\frac{1}{2}$ tons to the 12·5-inch of 38 tons, can be mounted either on dwarf or on casemate traversing platforms, the carriages being the same for both dwarf and casemate.

Dwarf traversing platform.—The dwarf traversing platform in all cases permits the gun to fire over a parapet 4 feet 3 inches high above the racer, at a depression of 5°. It is used with either A, C, or D pivot racers, the form of the emplacement being modified accordingly.

With A pivot racers, the imaginary pivot is in front of the platform, in the embrasure.

With C, the pivot is central and the racer a circle.

With D, the pivot is nearer the rear of the platform than the front.

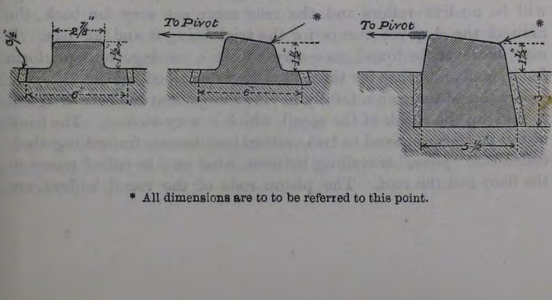
The table given herewith shows the nature and radii of the racers for each gun.

TABLE OF RACERS.

Nature of Gun.	Description of Platform.	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 dimensions are to to be referred to this point.

Casemate traversing platform.—The casemate traversing platform is used with a height for the sill of the embrasure varying according to the nature of the gun used. It is 2 feet $4\frac{1}{2}$ inches for the 7-inch gun, 2 feet 9 inches for the 9 and 10-inch, and 3 feet $2\frac{1}{2}$ inches for the 11 and 12·5-inch. This is due to the larger guns requiring more room for themselves and their fittings than the smaller ones, the gun being in all cases kept as low down as possible.

The casemate platform is not used with any other than A pivot racers.

Special mountings.—There are a few special mountings in the service besides these,

Counterweight carriages.—A good many 7-inch R.M.L. guns of 7 tons are mounted on disappearing carriages made on Moncrieff's counterweight principle; there are also two 9-inch 12-ton guns mounted in the same way, but this is unlikely ever to be repeated as the carriages weigh $2\frac{1}{2}$ times the weight of the guns.

Small port carriages.—About 30 10-inch and 12·5-inch guns 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; it answered very well on trial.

Mountings for new long guns.—The new R.B.L. guns which are being tried at Shoeburyness will undoubtedly require novel arrangements for their casemate mounting.

The 10·4-inch B.L. gun of 26 tons and the 12-inch B.L. of 43 tons will have to be put in the Spithead forts into emplacements now prepared for 10-inch of 18 tons and 12·5-inch of 38 tons, and the space is very restricted. The 26-ton gun will be tried at Shoeburyness mounted on a casemate carriage and platform somewhat similar to those now used for service guns, except that the carriage will be on live rollers and the rear racer set very far back, the radii of the A pivot racers for the trial being 8 and 22 feet. It may, however, be found necessary to use a carriage and platform for it, similar to that for the 43-ton gun described below.

For the 43-ton gun a totally novel arrangement has been designed to take up the shock of the recoil, which is very violent. The front of the platform is fixed to two vertical iron beams, framed together, called the "yoke," travelling between what may be called 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 platform to jump is almost done away with. The arrangement has answered very well on trial, and is adopted for service. It is, however, somewhat premature to give any detailed description of it now, until it has been actually used, but the following remarks may be of service. The gun and carriage will, as before said, go into an emplacement which will take a 38-ton R.M.L. gun; the radius of the rear racer is the same, *i.e.*, 21 feet 2 inches; 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 be 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."

Mountings for medium guns.—For a description of the modes of mounting medium guns see Lecture II.

Turret.—It is necessary to make a few remarks on the subject of the turret, as this is admitted to be the most perfect method of mounting guns.

Nevertheless, there is only one turret among all our English works, namely, that for two 80-ton guns at Dover Pier. A good number have been proposed, but this is the only one that has been carried out.

In fact, the size, weight, and cost of a turret, the necessity of using a steam engine to work it, and the very great care with which it and its surroundings must be made, and constantly maintained, all combine to render one reluctant to use it, unless for very heavy guns, or in very restricted sites, where nothing else can be placed. These two reasons are combined in the case of Dover Pier.

With regard to the position for a turret, it must be remembered that its peculiar quality, that of being able to give an all-round fire, can only be taken advantage of when there is a clear space around it, which is not often found, and which is a condition inconsistent with the association of other guns in battery with it.

This consideration also tends to the use in turrets of the heaviest guns only, which can be trusted to hold their own without much assistance.

There are, however, several reasons which seem to render probable the increased employment of turrets in the future. One is the introduction of breech-loading guns, which does away with the necessity for loading from under the glacis, and renders it possible to load inside the turret without making the latter of a greater interior diameter than the length of the gun, as had to be the case when a muzzle-loader was used. This reduces size, weight, and cost.

Another reason is the increased protection necessary against projectiles, which will render sites which were large enough for an ordinary battery, now too restricted for anything but a turret.

Another is the increased complexity of the guns and their gear; when so much care has to be given them, the turret and its belongings may get properly looked after also. It must be admitted, though, that this complexity would render one very loth to put up turrets out of England, although circumstances may compel one to use them at some of our very important fortresses abroad.

The last reason is, that it is becoming very desirable to mount some very powerful guns in several of our fortresses. Of these guns we shall certainly have but few; they must therefore be mounted securely, in such a manner as to command as large an area of water as is possible; also it is probable that they must in any case be worked by machinery. All these considerations combined, point to the employment of turrets in addition to our present coast works.

In land works the case is different. Here there is no such great advantage to be gained by the use of very powerful guns as there is in coast batteries, and there is seldom any absolute necessity for putting the guns in a particular place. Moreover, a land turret would have to be nearly as strong, and therefore as costly as a coast one, for the enemy would certainly get up two or three armour-piercing guns for its especial benefit. Consequently, turrets are not likely to come into use for land works.

It may, nevertheless, be noted here, that of all armoured structures, the turret is the best for land works, as it can turn its port aside when not actually firing, and can thus give complete protection to the gun detachment against the accurate missiles of the present day.

Of the construction of a turret much cannot be said. The general form is familiar from its use in ships.

It would contain two guns, as they can be mounted in a turret very little larger than is required for one only. The substructure would probably consist of a drum or circular mass of masonry, carrying the pivot and the roller-path on which the turret revolves. Around this drum would run a passage by which ammunition would be supplied, and access obtained to the interior of the turret. Any signalling gear or speaking tubes must pass down the axis of the drum.

An armoured ring must encircle the base of the turret, to obviate any chance of its being jammed by a shot striking the surface of the glacis close by. It is useless attempting to give more particulars, seeing that nothing definite can be laid down.

Cupola.—A cupola, which is a form of turret with sloping sides, carrying light armour to resist medium guns, is to be tried by firing from it and at it. It is to contain one 10·4-inch 26-ton B.L. gun, and is to be worked by manual labour. The diameter will be about 24 feet. If successful, cupolas are likely to be much used.

4. CASEMATES.

Emplacements which take casemate platforms.—Guns on casemate platforms are mounted either in masonry casemates with iron shields; or behind open-battery shields, as they are called, the latter being 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 papers (see Lecture IV., p. 135), 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 platform, 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 platform, 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 platforms issued by the Royal Carriage Department will supply the necessary information, but the dimensions and arrangement of the platforms 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.

Arched casemates.—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 should be 12 feet wide, 9 feet high in the centre, and 7 feet 6 inches to the springing.

The shield for a double tier work (which would not now be used) may simply be considered, as 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 case-shot 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.

Weakness of piers.—No longer advisable to use masonry casemates.—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, and, consequently, it is no longer advisable to use this form of construction in important works, but to adopt some form which permits of greater strength being attained.

Iron overhead cover. Plate XXI.—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.

One of the latest developments of the shield with iron overhead cover is exemplified in the battery shown on *Plate* XXI., 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 condition of existing work in the ammunition stores and foundations, and in building a new work it would probably be more economical, and would give even greater strength against attack, to adopt a continuous iron front; but the plan is a very convenient one and may be followed with advantage, even in cases where such large shields cannot be used.

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 in 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, such as we have in this case, but which is wanting in some of the older casemated batteries.

Open battery shield.—A commoner form than the above, and one which has some advantages from a defensive point 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 shewn in *Plate* XXI.

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 too restricted for any other form of casemated battery.

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 is not uncommonly applied on board ship, but on land there are not many examples, and with the introduction of long guns, which will be very difficult to treat in this way, it does not seem likely that more will be built.

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 is 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 proves useful on occasions.

New 15-foot shield with iron overhead cover.—A new shield has recently been designed, which will probably be used in future constructions when masonry piers are employed instead of the old 12-foot shields.

It is very similar in design to the 20-foot shield before mentioned, but is only 15 feet wide; the plates are each 10 feet high and 15 feet long, and are bolted at top and bottom against horizontal girders, which are carried 5 feet into the piers at each side. The lower girder is also partly bedded in the floor. Behind the top girder is another one assisting to carry the ironwork of the roof.

The shield and front racer should be carried on a platform of granite or hard stone blocks, which should be prolonged under the ends of the lower girders; the latter should also be backed up with hard stone blocks in the pier.

The pier itself should be built with a facing of ashlar masonry up to the under side of the top girders, the top course being shaped to fit them and to assist in holding them, and the whole top of the work over the piers, as well as over the iron roof, should be finished off with a mass of concrete from 4 to 5 feet thick, embedding the ends of the girders and holding them securely.

For a 10-inch R.M.L. gun of 18 tons, a casemate with this description of shield may be 8 feet high from the floor to the under side of the roof girders.

This casemate will be somewhat more expensive than the old masonry casemate with a 12-foot shield, but events have rendered its adoption necessary.

5. BARBETTES.

Emplacements to take dwarf traversing platforms.—*A pivot emplacement.*—Guns on dwarf traversing platforms, 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 platform.

C and D pivot emplacements.—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 of 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 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 enabled the numbers loading to stand high enough to enter the charge and ram home, and also allowed 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.

This forms the present type of barbette battery. 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, and the gear in the platform being still unchanged, the men while traversing, elevating, serving the vent and pointing the gun, have to stand on the drum or on the platform, and are just as much exposed as they were before. Still it is a great improvement on the old method, although it does not yet come up to the ideal of a barbette emplacement, which should protect the detachment from all small projectiles, and experiments are in progress with a view to improving it. See pp. 166 and 181.

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 platform, 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 way for the loading stage, which is 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 carying 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 feet 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 1 foot of the drum should be left in front of the racer for the sake of strength.

If, as is the case with 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 radii of the front part of the emplacement being determined by this section, the plan of the rear part remains to be settled. This depends on the amount of space required for working the handles of the traversing gear, for elevating and pointing the gun and the other operations that cannot be done from the level of the loading way, and the gear for which is arranged as if the gun was working in a level emplacement.

It becomes necessary, therefore, for convenient working to expand the drum in rear so as to surround the platform at all angles of training.

This requirement combined with those ruling the shape of the front, results in a form such as is shown in the plan, *Plate* XXII.

The parapet follows the form of the drum, leaving a space for the loading way.

Arc of training for C pivot emplacements.—The conditions governing the form limit the employment of a C pivot emplacement for heavy guns to cases where 130° is a sufficient arc of training. If a larger arc is wanted, it becomes necessary to use D pivot racers, when from the tail of the platform being nearer to the pivot, and the radius of the drum in consequence larger, there is always room on it enough to work the traversing gear, &c., even if the gun be given an all round fire.

The increased size of the D pivot emplacement renders it objectionable, and it should never be used if it can by any possibility be avoided.

If a gun is intended to fight mainly in one direction, but may be wanted to fire one or two shots at an extreme training; if, for instance, it is intended for the defence of a channel, but it is wished to have the power of firing one or two shots at a ship that may have got past, it is usually best to use a C pivot emplacement arranged to suit the cases which would most often occur, and for the extreme fire not to insist on the tail of the platform remaining over the drum. It is inconvenient but not impossible to work it this way, and by not adopting the D pivot more security and rapidity of fire is obtained during the first part of the fight.

Two points require attending to—one, that the parapet gives room for the platform to traverse round; the other, that the racer blocks are firmly fixed where the shock of recoil comes on them. The expansion of the drum in rear has the advantage of backing up the racer blocks strongly and of enabling them to resist the force of the recoil which passes through them.

Since writing the above it has been decided to alter the platforms of guns on C pivot racers, so as to admit of their being traversed from the sunken way. This will involve cutting off the expansion of the drum in rear, and thus reducing the support given to the racer blocks. Good work will have to be used about them in future or they will be displaced by the firing. The guns will also be turned to one side for loading, under the protection of the traverses, in cases where the construction admits of it. Experiments to determine the best details are being carried out. In the meantime it may be assumed that 160° is the largest arc of lateral training that it will be possible to give an R.M.L. gun mounted in an emplacement arranged for "under-cover loading." See p. 181.

6. POSITION 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 very necessary to push the guns forward in order to get the fullest effect from their penetrative power at long ranges, and this condition often necessitates placing the batteries on the low ground close to the water, where they must be casemated, unless indeed shoals stretch out so far in front of them that a vessel cannot get near them.

It should always be remembered that the height of a battery only tells at short ranges. At 2,000 yards a height of 100 feet only subtends an angle of about 1°; an amount which is too small to make any practical difference in the security of the battery. It used to be considered that a low battery had a better chance of hitting than a high one on account of the flatness of the trajectory. The introduction of Range Finders has, however, put the advantage on the other side for the present, as the depression instrument now in the service (see Lecture VII.) acts best when at some height above the water.

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 good shooting for machine guns from ships, and with batteries 100 feet above the sea, the trajectory at that range would be nearly horizontal, so that a properly made parapet would protect the battery from such projectiles. It would not protect it from shells, but until they can be burst with accuracy, carefully designed barbette batteries are still admissable. The invention of a perfect time fuze would do away with all barbettes.

At lower levels than 100 feet casemates or turrets should be used.

Combination of barbette and casemate.—A good combination is casemate and barbette together, the casemate emplacement forming traverses to the barbettes. The enemy would have to fire two different kinds of projectiles, for shrapnel would not be of much use against shields, while armour-piercing projectiles are not so likely to strike the barbettes. On the side of the defence the advantages are gained of economy and of a large arc of fire for the guns *en barbette*. Even if such a battery were at a low level the barbette guns might do their share of the fighting at long ranges, and leave the casemate guns to take it up when the enemy came in close.

If cupolas with sloping sides and light armour be adopted, as is probable will be the case, for the new long B.L. guns, it will still be advisable to place them at a height above the water in order that shot may have an additional tendency to glance off them.

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, &c., which can be only partially closed, and has at least masts 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 will also be useful against gunboats firing from long ranges.

Rifled howitzers.—It is a pity that rifled howitzers cannot be more used for the purpose of attacking ship's decks. The accuracy of their fire is doubted, but they do very well against land works, and the use of position finders, which would enable them to be directed beforehand on to the spot that a ship was about to pass over, would seem to diminish this objection to their employment. I have no doubt that they will come into favour when once they are tried in real warfare.

LECTURE VI.

1. CASEMATE DETAILS.

Casemate Floors and Fittings on them.

Casemate floors for a heavy gun.—The floor of a casemate for a heavy gun should be solidly constructed, as it will have to carry a considerable weight, and to resist the shock of recoil. If resting on arches, the total mimimum thickness should not be less than 3 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 should be prepared to shew 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 should be 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 feet or 5 feet of concrete, as, if there is the least jump of the platform, the whole force of the recoil is transmitted to the rear racer.

In some of our older works, the rear racers are laid on oak blocks, but this should not be repeated. 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 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 has 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 is requisite.

The centre lines of the racers at the intersection should be drawn full size, so as to give the exact angle at which they cross.

Besides this, the general survey of the racers has to be very accurate, or no end of trouble is the result.

Tested steel tapes should be used in taking the measurements, the length of the trammel used for laying down the curve of the racer should be perfectly accurate, and the exact distance between the pivots must 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 the end of this Lecture, p. 183.

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 $\frac{\text{Genl. No. 5.}}{\text{563.}}$ 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 mimimum, 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.

Graduated arc.—Be sides the racers, there is on the floor of the casemate, the brass graduated arc for use in position finding. (See I.G.F's. Circular, No. 292, dated 1st November, 1879).

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 on.

When a crossing plate interferes with a graduated 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 4 inches interior diameter, 2 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 ring bolt 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 should be of the most massive construction that can be conveniently provided, so as to oppose the greatest resistance to displacement.

The exterior should be built of granite or other hard stone, as the hard face assists greatly in stopping the shot that may strike it.

The inner face should be formed of ashlar masonry, and the hearting may be either ashlar or cement concrete All the stones should be set in cement.

Stones which are easily cut may be shaped with hollows and projections to fit into one another, so that they may be difficult to shift.

Hard stone dowels are, I think, objectionable, but hoop-iron bond might possibly be used with advantage.

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 may with advantage be increased to 4 or 5 feet, or even 6 feet.

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 should be set back 10 feet from the edge of the escarp, as shewn by the dotted line in *Plate* XXI., and the shield 4 feet behind that again; this is intended to give security against a shot penetrating just under the shield, and disturbing the floor of the casemate and the racers, for with this arrangement, a shot striking anywhere near the top of the escarp would probably be defected, and turn out before reaching the shield.

Range dials and fighting lanterns.—The only fittings on the piers will be 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 said in connection with range finding in Lecture VII.

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 moveable.

It may be observed that in addition to these lamps, the No. 1 of the detachment would be provided with a hand lamp to read the graduated arcs by, and also that 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 is 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 does not much matter as far as the arch is concerned if it be solidly built, but it will be found necessary to give it careful consideration before beginning the construction. I myself prefer making the curve of the sloping arch the same as that of the main casemate arch, and setting 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; I believe, though, that this is the simplest mode of construction. An elliptical cross section can be used if wished, or a sloping springing; or, what is sometimes a good arrangement, the intersections of the arches, instead of being groined, may be ribbed like a Gothic arch. This suits the case of there being a limited supply of good material, which should be used for the ribs, and the inferior stuff for the filling-in between them.

The front of the arch, as of the piers, should be granite or hard stone, and it should be carried back, for several feet at least, in ashlar masonry. Brickwork or concrete can be used if there is nothing better available, or if economy is a great object, but in this case it might be advisable to have an iron hood in the interior, connected with the shield frame, which would serve to support and strengthen the arch.

The external arch stones should be massive; they are usually built in two rings in the manner shewn in the drawing, *Plate XX.*, where the correct positions of the joints is given, and the intersections of the curves for an arch for a 12-foot shield.

Overhead loops.—In the arch are fixed two or three iron loops for suspending the gun to 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 $\frac{1}{2}$ 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 the new long B.L. guns will probably be different, but will depend 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 eyebolts 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 eyebolts. 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.

The top of this should be rendered with cement or asphalted, and it would be a good thing in addition if the asphalte could be covered with about 3 feet of soil which would preserve it from deterioration.

Loading bar.—There is another fitting in a casemate 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. They are of a variety of shapes to suit different forms of shield. The portions close to the gun are made moveable, 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*, 1881, paras. 262 to 269.

Port bar.—The port bar is an iron bar put across the port during the operations of loading, 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 : No. V. / 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 *Army Circulars*, Clause 141, September, 1877).

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* XXI.). This rounding may be formed with brick set in asphalte, or with asphalte tiles set in cement.

The shield which will be used in future works will probably be 15 feet wide and of the Seaforth construction, *i.e.*, supported top and bottom by horizontal girders, with their ends built into the piers.

With this shield, and merlons of the proper size, that is, about 30 feet long, it is probable that the expense of a casemated battery would be so great that it would be preferable to have a continuous iron front. The 15-foot shield, however, will be useful for isolated casemates.

Mode of Loading.

Mode of loading in a casemate.—The mode of loading 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 platform, 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 realizing 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*, 1879."

2. BARBETTE DETAILS.

The following is a description of a barbette emplacement, such as has been recently constructed. Some of the details will be altered when under-cover loading is adopted, but the changes in the actual emplacement will not be extensive. They are mentioned at the end of the description. For a drawing of a barbette emplacement for a heavy gun see *Plate* XXII.

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-pr. 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 platform, into the bore of this gun. It is made to fit the 24-pr. or 32-pr. used.

Racers.—Around the pivot is the racer or racers. These are set on granite blocks, like the rear racers in casemates, or on iron chairs, as will be hereafter described, their position being determined by the pivot.

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 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 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. They are very easily deranged, and heavy shell will be very effective against earthwork.

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. 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 $\frac{5}{8}$ of an inch above it, and care must be taken that this height is kept clear or the moveable loading stage will be thrown off the rails by its flanges striking the concrete.

There is a tendency for the stage to leave the rails, and one is to be tried with flanges $\frac{3}{4}$ of an inch deep to its trucks instead of $\frac{1}{2}$ an inch. If this alteration be adopted, the rails will have to project higher above 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, from Messrs. Bird and Co., Laurence Pountney Hill, London, E.C., who have the rolls for making the proper section; any rail, however, of nearly the same section may be used.

The moveable loading stage and its rails will be unnecessary with under-cover loading, still in cases where it exists it will be advisable to retain it, in case of accident to the fittings of the other system.

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.

The inner face of the parapet is 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.

Shell shelves.—The shelves for projectiles are also recessed in the parapet, and are made of dimensions to suit the gun.

Those for a 10-inch gun are 2 feet $9\frac{1}{2}$ 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 is to enable projectiles to be kept ready for use close to the gun, in a convenient position for loading. If moveable loading stages be done away with, these will follow them.

Ringbolts.—Round the emplacement three or four strong ringbolts are fixed for convenience in mounting the gun, as in casemates.

They are usually placed above the shell shelves about 2 feet below the crest. They should be countersunk so as to be out of the way.

Eyebolts.—At a height of one foot above the floor of the sunken way, are several small eyebolts to take the snatch block of the tackle which is attached to the muzzle derrick for raising the shell to the muzzle.

They may be made of $\frac{7}{8}$ of an inch round iron, with an eye $1\frac{1}{2}$ inches in diameter, and are fixed in the man recesses when there are any.

Foundations of parapet.—The foundations of the concrete portion of the parapet require to be carried deeply down; not so much to avoid displacement as in the case of the foundation of the drum on which the gun stands (for a settlement of the parapet does not matter much), but in order to protect the drum from the enemy's projectiles. Emplacements exist which are fairly strong down to the level of the interior, but from the concrete stopping short at that point it would be easy for a heavy shell to penetrate underneath the gun, and to blow up the whole affair.

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. Of course the quality of the concrete may be reduced as it descends; the thickness must be uniform, or increasing, for constructional reasons.

Derrick or davit.—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 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, is a small jib crane made of 2-inch bar iron. It is 4 feet high, and has a radius of 2 feet $7\frac{1}{2}$ 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 3-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. The davit will be used with under-cover loading.

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 Clause 141, *Army Circulars*, September, 1877.)

Mode of Loading.

Mode of loading.—The following is a short description of the mode of loading.

The projectile is brought up from the shell store in a truck and hoisted on to the moveable 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 8 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.

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.

3. UNDER-COVER LOADING.

Rear loading for 38-ton guns.—In order to remedy this and also with a view to get increased rapidity of fire by giving the men more room to work in, a plan was tried at Cliff End Battery of turning a 38-ton gun to the rear to load. A fixed stage or "loading "pillar" was built against one of the merlons, carrying a cast-iron trough on which the shot was deposited by means of a davit. The traversing gear of the gun was altered to allow of its being worked from the level of the sunken way, the tail of the drum being cut away so that there should be no interference with the traversing gear in any position. When it was required to load, the gun was turned round to the rear, sponged out, and the cartridge entered, and then turned to the trough and depressed to 8°. The shot was then rammed home in the ordinary manner, but the men having plenty of room were able to work with greater freedom.

The results were so satisfactory that it was determined to have a fresh trial with additional modifications. The loading trough is to be enlarged so as to contain both the shot and cartridge in readiness for the gun; the traversing gear is to be worked from a fixed winch in rear of the gun, the power being taken to the platform by means of shafting, and the elevating, pointing and firing is to be done from the sunken way under the chase of the gun. In order to permit of the gun being fired without inconvenience to a man in this position, the radius of the emplacement has been reduced by 3 feet.

To carry out these proposals an alteration of the elevating gear has to be made, reflecting sights fitted and an electric firer devised. The No. 1 of the gun will then have the power of following every movement of an object and of firing the instant he wishes.

If these alterations are successful the rapidity of fire will be increased; the gun detachment will be always under cover, except (for a short time) the man who serves the vent and primes; and the aiming will be much improved. In fact the barbette mounting of a 38-ton R.M.L. gun in a C pivot emplacement will be really satisfactory.

Under-cover loading generally.—It remains however to deal with all the other heavy service R.M.L. guns which are mounted *en barbette.*

For these it has recently been decided to alter the traversing gear of the guns mounted on C pivot racers, so as to enable it to be worked from the level of the sunken way, and to load from behind the traverses, the shot being placed in an iron trough on a " loading " pillar " in readiness to be rammed home, in a similar manner to the first experiment with the 38 ton gun, but with a modification which will enable the rammer to be always in position for use.

This involves making the drums circular and constructing the fixed loading pillars.

It has not been thought expedient to incur the expense that would be involved in making arrangements for elevating or aiming from under cover.

These alterations will evidently much improve the security of the detachments. They have not yet been actually tried, but will be shortly.

It can, however, I think, be already laid down that the service R.M.L. guns, arranged for under-cover loading, will not be able to fire over a larger arc than 160°, and that a space of 30 feet on either side of the pivot should be allowed for working a 10-inch gun; rather more for a 12·5-inch, rather less for a 9-inch. It follows from this that it is not every emplacement that can be altered for under-cover loading.

It may be observed that the reduction in the size of the drum from which the gun is fired will render very solid building necessary, or it will be shaken and displaced by the shock of recoil.

R.M.L. guns mounted on D pivot racers cannot be treated in this way; luckily there are very few of them, other than 9-inch. A pivot emplacements must, I think, either be converted to C pivot or shielded, if additional protection be required.

Sir W. Armstrong's protected barbette.—A system of under-cover loading, which has been worked out by Sir W. Armstrong for long R.M.L. guns, and which has been used by some Governments, is about to be tried at Shoeburyness. 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 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.

A further description of it in its present stage might prove of small value, while, at the same time, one cannot forecast the alterations that may be made in it. There are, however, three characteristics that can hardly be changed, and which must affect any decision as to its employment; they are the following:—the emplacement, with the rammer chambers, must cover a great deal of ground; it must be very difficult to give it efficient protection against enfilade fire; and the accuracy of the fittings must be extreme, or the loading arrangements will fail to act.

4. RACERS.

The most important part of a heavy gun emplacement is the racer on which the platform 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 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.

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 Table of Racers, Lecture V., p. 153.

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 rests.

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 has not yet got its shield, the imaginary pivot must be localised as nearly as possible.

It is usually 8 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 4 parts lead and 1 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 amalgam 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 platform, but it will affect the sights and graduated elevating arc 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 groves might be cut to receive them.

In the lithograph attached to I.G.F's circular No. 250, is shewn 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 platform before being leaded in.

The platform 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, 1 inch thick and generally 3 inches wide, except when intended to be used at the joints of the racers, where they are 6 inches wide.

They are 1 foot deep over all, and have a flat surface 7 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.

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.

I have gone somewhat minutely into the subject of racers, because racers share with magazines the distinction of being the subjects about which questions most commonly arise with the Artillery, as most directly affecting their "materiel," and it is therefore advisable to thoroughly comprehend the minutiæ connected with them.

5. GENERAL ARRANGEMENT OF BATTERIES.

Casemate Batteries.

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 shewn in *Plate* XXI. 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 platform, 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 blows of projectiles, 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. In distant places where first-class ironclads are not likely to be seen, we may be satisfied with a less thickness, say 30 feet, and a section might be adopted such as is shewn in dotted lines on *Plate* XXI.

Arrangement of magazines.—A plan of magazines to suit this section might 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 can 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 100 rounds per gun.

On the gun floor the lifts issue in the middle of the rear piers of the casemates, which are rather larger than is usual. 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 can 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 all together, 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. 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.

General Arrangement of Barbette Batteries.

In speaking here of barbettes, C pivot emplacements only are referred to, as neither A nor D pivot should any longer be constructed.

Intervals between the guns.—The first thing to be considered is, at what distance apart shall the guns be placed?

In some of our old works, where 9-inch R.M.L. guns have been mounted, the distance is as little as 30 feet, and there are no raised *bonnettes* to separate one from the other. I have not been in any one of these batteries while the guns were being fired, but the effects of concussion on the detachments of the guns adjacent to the one fired must be very unpleasant. Moreover, from the want of traverses, and from the nearness of the guns to one another, an enemy's projectiles are not likely to fail to produce an effect, wherever they may fall in the battery.

In later constructions the interval between the guns has been much increased, so that it has risen to from 90 to 100 feet. This permits of the isolation of the guns by large and solid traverses, at least 30 feet wide at the top, without retaining walls, and formed with easy slopes, which would exercise some real effect in checking projectiles, and which would not be blown to pieces by a shell exploding in them.

The separation of the guns would probably limit any injury to a single emplacement, and their distance apart would render it necessary for the enemy to aim definitely at one in particular and not, so to speak, to "fire into the brown."

It would be desirable to separate the guns, so that the fragments of any one shrapnel shell, which, of all projectiles, covers the largest area, should not be able to strike the men in two emplacements. To do this, however, the interval would have to be more than 100 feet, for the lateral dispersion of a 64-pr. shrapnel is 150 feet, and that of the larger guns is probably greater, but it is not often that the conditions of the site on which a battery has to be built will admit of such an extension as this.

If, however, it be possible to do it, the guns may be spaced at 100 yards instead of 100 feet.

Enfilade fire will be always very trying to a barbette battery of heavy guns, on account of the space the battery must cover, which makes it easy to strike somewhere within it. No amount of traverses can wholly remedy this, and barbette batteries should, whenever it can be done, be so placed as to be free from the danger ofenfilade; if that be not possible there should be high traverses, and wide intervals between the guns; without these precautions a battery cannot be expected to be long in action without being silenced.

Communication in rear.—Along the rear of a barbette battery should run a way sunken about 7 feet below the level of the emplacements, so as to give additional security to the communications between one point of the battery and another, and also to afford access to the expense ammunition stores.

Position of ammunition stores.—These may be either under the traverses or under the gun emplacements. The former position is the commonest in old works, as by adopting it the convenience was gained of serving the ammunition to the guns on the level or nearly so, but without the use of a great deal of concrete, sufficient protection cannot now be got in this position, except for stores of small dimensions; the floors even of these must be sunk below the level of the emplacements, unless the guns are very widely spaced, and the traverses consequently very large. It results from this, that the guns can no longer be served on the level directly from the ammunition stores.

Being therefore obliged to use either ramps or lifts for bringing up the ammunition, and masses of concrete being required for the protection of the stores, it is evident that the concrete parapet which has to be built round the gun emplacement, and which has to be carried down some depth to protect the foundations of the drum, may be utilised to cover the ammunition stores as well, by placing them behind it and under the level of the emplacement.

It is best not to place the stores immediately under the gun but in rear of the drum, as it is then possible to inspect the roofing, and to keep it waterproof, while if it were under the drum the asphalte might be cracked by the firing, and could not be mended. Moreover, the emplacement and the stores being quite distinct from one another, can be altered independently; this is a consideration always to be kept in mind in matters of fortification, since changes are constantly taking place.

From this position, the ammunition can be hoisted to the emplacement level by means of lifts issuing in rear of the merlons on each side, points which are convenient for the present mode of loading, and will also be well suited to side or rear loading, as the charges will be delivered close to the muzzle of the gun.

If the concrete part of the parapet be 10 feet thick, and formed approximately into a semicircle or horse-shoe shape, it will be found in the case of a 10-inch R.M.L. gun, that there is room enough behind it to place stores for 100 rounds of cartridge and of shell, together with small serving rooms, shifting accommodation, and a lamp passage, so that the gun can thus be completely provided with its expense ammunition. Consequently this arrangement gives a unit both in the matter of storage and of construction; which is a convenience both in building the battery, and in working it when completed. The blocks of building forming the stores and emplacements will be entirely independent of one another, and the traverses between them may be mere mounds of earth.

Exterior form of the battery.—Whatever position may be chosen for the ammunition stores, the exterior shape of the battery will be the same. The traverses should rise about 4 feet above the level of the crest of the emplacements; they should be formed with very easy slopes, say 2 in 1, and all the intersections of slopes should be rounded off so as to shew no sharp-edged shadows, which might assist the enemy's aim. The intersection of the exterior slope of the traverse with the superior slope of the parapet may coincide with the extreme line of fire of the gun. The full height of the traverse need not be continued close up to the emplacement where there may sometimes be no room to make it wide and solid. It is better to have a central block about 30 feet by 30 feet on the top, of the full height of 4 feet, and on either side to lower it to the height of a foot or 18 inches. Feather edges of earth are of no use in a coast battery.

Look-out places.—The traverses will afford convenient places for observing the effect of the fire from, and it will be necessary to form small recesses in the rear slopes, about 5 feet deep, for that purpose. As a rule these may be left to be made when wanted, being dug out and revetted with gabions, but one or two would be useful for practice in peace time.

The shape of the traverse where it immediately adjoins the emplacement will in future depend on the exact arrangement adopted for under-cover loading, but the concrete part of the parapet may, in any case, be ended about square with the tail of the platform when central, and two safe corners be thus formed, one on either side of the gun, where the lifts may issue, or ammunition recesses be placed. The loading of guns adapted for side loading will be done here, and may require the concrete to be sloped up for an additional foot or 18 inches.

Coast Batteries in General.

Flanks of heavy gun batteries—Medium gun armaments.—The flanks of a heavy gun battery should, as a rule, be provided with one or two medium guns for flanking the coast and for opposing any attempt at a landing, for it would be a waste of power to use armour-piercing guns against boats, and, moreover, the rapidity of their fire is not likely to be sufficiently great for operating against a number of small assailants. These medium guns may be mounted either *en barbette* or in haxo casemates according to circumstances. At present the 7-inch R.M.L. of $6\frac{1}{2}$ tons is the best gun to use, if a barbette mounting be required, as its 6-foot parapet platform is the best in the service. In future works, no doubt, the 6-inch R.B.L. or some similar gun will be used, and this will have the advantage that at short ranges it is capable of penetrating a considerable thickness of iron, and will thus add to the power of the battery even against armoured vessels if they attempt a close attack.

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, 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 3 or 4 guns, the accomodation 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 6 or 8 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.

Storage Requirements of a Coast Battery.

Cartridge store—Shell store.—There should be cartridge store accommodation for 100 rounds per gun, and shell store accommodation for 100 loaded shell, and there may be a main magazine for the remainder of the allowance of ammunition for the guns.

Recesses.—If the points of issue from these stores be far from the gun to be served, say 60 feet or over, recesses should be provided close to the gun to hold 12 rounds or so each. (See page 118.)

Fuze and tube shelves.—Fuze and tube shelves should be fixed in every shell store and shell recess. (See page 104.)

Artillery stores.—An artillery general store is required in each battery, and in open batteries a side arm store and a small store are required, each for not more than eight guns. (See Lecture VII.)

Laboratory.—A laboratory (see page 118) for making up cartridges and filling shell is required in every very large battery or for a group of batteries. For a small battery some place for filling shell is sufficient; the cartridges would be sent to it made up for use.

LECTURE VII.

1. ARTILLERY STORES.

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. Field forge store.

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 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.

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. These compartments may be about 2 or 3 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.

Heavy guns in casemates require no small store accommodation, because their fittings are left permanently with them; also M.L. guns require less than B.L. guns.

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 six feet six inches to seven 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 accomodation, may be obtained by consulting the "Manual of Siege and Garrison Artillery Exercises, 1879."

Field forge store.—4. The field forge store is intended to hold the various articles required for making small repairs to the ordnance and carriages. One might be allotted to each large fort, or group of forts.

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.

Nomenclature of stores. Lettering circular.—For the proper naming of these and other stores, see the "Nomenclature of Artillery Magazines and Stores," and the Equipment Regulations, 1881; and for the proper style of painting up their names, see Army Circulars, Clause 141, September, 1877, on Lettering Emplacements and Accessories in Works of Defence. Some slight modifications of these will however appear in Revised Army Regulations, Vol. V.

2. PROVISION TO BE MADE IN COAST WORKS FOR SUBMARINE MINING APPARATUS.

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 accomodation is, however, sometimes required for observing stations, test rooms, and electric light apparatus.

Observing stations.—An observing station should be 16 feet long by 9 feet wide, exclusive of any stairs to the test room, which should be close by, and to which the wires should be taken. It would be a lightly built room, with two observing windows at the angles of one of the long sides. It may be remarked that a building of this character should not be exposed to the view of the enemy. If it cannot be concealed something of the nature of the look-out station described in p. 206 might be used instead.

Test room.—The test room should be bombproof; its dimensions are 20 feet by 16 feet, by at least 6 feet 6 inches high.

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-H.P. vertical engine, driving a dynamo-electric machine by bands, or by a Brotherhood engine, combined with two dynamo-electric machines, to which the engine is coupled direct.

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 21 feet by 8 feet.

In the second case the boiler is 8 feet high, and 3 feet $8\frac{3}{4}$ inches in diameter, and it is separate from the engine and electric machines, which, altogether are 9 feet $3\frac{1}{2}$ inches long by 2 feet 9 inches wide, and 3 feet 7 inches high, standing on a base 4 feet 9 inches long by 2 feet 9 inches wide.

These machines should be under bombproof cover, and should be protected against horizontal fire. A coal store will be required.

The position and arrangements of the electric lamp must be decided locally, but it would probably be placed on the end of a shaft, and raised and lowered vertically through a hole in the roof of a casemate. For further particulars see the Manual of Submarine Mining, 1880.

3. 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 in batteries, mainly because this last objection to speaking tubes is much greater in the case of telephones.

Construction.—The tubes used up to the present in our works have been made of 1-inch iron gaspiping, 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, and $1\frac{1}{2}$ 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 whistle has been blown. When the tubes issue in places where they are accessible to everybody, as in a barrack room, the whistles should be removable, and the ends of the tubes should be closed by screw plugs, capable of being taken out only by means of a key, like a railway door key. Mouth pieces, whistles, and other fittings will 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 four feet nine 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 be easily 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 that wooden whistles soon get broken.

4. RANGE AND POSITION FINDERS FOR COAST BATTERIES.

The great cost involved in mounting the heavy armour-piercing guns of the present day has led to a corresponding reduction in their numbers. The value of each round is therefore much increased, and with it the importance of not throwing away a single shot, particularly when such a shot may effect so much. Moreover, projectiles retain considerable armour-piercing power at ranges much beyond those at which they would at present be used; the reason for not using them at these long ranges being the uncertainty of their striking the mark.

In order that ammunition may not be wasted through inaccuracy of fire, experiments have been made with a view to obtaining a system of range or position finding, which will render the shooting more or less independent of the judgement of the No. 1 of the gun.

Range finder.—A range finder is an instrument which will measure the range only.

Position finder.—A position finder is an instrument, or set of instruments, which will identify the actual position of the object observed. Thus while, with a range finder, the No. 1 has to point the gun, the information furnished him merely enabling him to give the right elevation, on the other hand with a position finder, no one need look over the sights at all; the elevation and lateral training to be given to the gun, in order that the shot may strike the object, is communicated to the detachment, and they merely place the gun in accordance with these instructions and fire when they are ready.

A position finding system has many advantages over a simple range finder; it enables the gun to be fired with accuracy when the view from the battery is obscured by smoke; it gives a ready means of concentrating several guns on one ship; it does not require such skilled men for Nos. 1 of the guns as the service method does; the guns are directed by men in a secure place, and away from the bustle of the battery, and who are therefore likely to direct them with judgement.

A range finder is, however, simpler than a position finder, and can be used in any suitable place without the preparations and surveys that are necesssary with the latter.

Range finders for coast batteries.—Depression range finders.—There is only one range finder for coast batteries in the service at present, namely, Captain Watkin's depression range finder, which is superseding the same officer's range finder for elevated batteries which used to be issued.

Both of these instruments start from the same principle of measuring the distance to a ship by determining the angle of depression of the line of sight directed upon its water line, the height of the point of observation being known. But the range finder for elevated batteries was merely a bent glass tube partly filled with liquid, the range being determined with the aid of certain boxwood scales, by observing the point at which the surface of the liquid rested when the telescope on the top of the instrument was directed on the object. On the other hand the new depression range finder is a carefully constructed instrument of metal, somewhat resembling a theodolite, with a small horizontal plate, and with a graduated bar having a sliding support under the telescope, by which it is adjusted, so that it can be set for the height at which the instrument stands above the surface of the water; it also has a cylinder with a spiral line on it graduated in yards, by rotating which the telescope is elevated or depressed, and off which the range is read, when the telescope is directed on the water-line of a vessel.

This range finder may be used for a height of as little as 60 feet above the water level. For heights less than this there is as yet no range finder in the service. Instruments of that class which contains its own base would be suitable for this situation if they were not either inaccurate or cumbersome. The Berdan range finder, which is said to be one of the best, would require as much room as a 64-pounder gun, and would be very liable to injury.

Position finding.—One position finding system has been tried at Plymouth and elsewhere, and another is about to be finally tested at the same place; both are approved, and it is probable that both will be adopted into the service, for use in suitable localities.

They are both the invention of Captain Watkin, R.A.

Electric position finder—One of these, namely the electric position finder, works by the measurement of horizontal angles from the ends of a long base. It is arranged in the following manner: at each end of the base is a telescope, which is electrically connected with an arm moving over a chart placed in a room in the fort, in such a manner that, when in proper adjustment, each telescope and its corresponding arm are always parallel to each other. The arms are pivoted at those points on the chart which represent the stations containing the telescopes, so that when the telescopes at the ends of the base are directed to any point the intersection of the arms gives the position of that point on the chart.

In order to identify at once the position of the intersection of the arms, the chart is divided into large squares, which are numbered, and each of these again into twenty-five smaller squares, which are lettered, A, B, C, etc.; these small squares represent an area of 40 yards by 40 yards.

When a ship is being followed by the observers at the telescopes, the number and letter of each square it passes into, as denoted by the intersection of the arms on the chart, is read off. This information is immediately transmitted to the gun detachments, by an electrical mechanism, by which the number and letter are shown on a small instrument, called a range dial, fixed between the guns, or in any convenient place where it can be easily seen and is secure from injury.

In order that this information may be of use for the guns, it must be readily translated into degrees of training and elevation; and for this purpose each gun or group of guns is provided with a table, drawn out on a large sheet of cardboard, and called a range card, and made up into some convenient form; on it is shown each square with its number and letter, and with the range and the angle of elevation, and angle of lateral training, which will direct the projectile from that particular gun or guns into the centre of that square.

A man is stationed opposite the range dial with this card; as the numbers and letters appear, he reads out the corresponding angles of elevation and training, and the gun is moved in accordance with them by the detachment.

The lateral training is given by means of the graduated arc, fixed in the floor, and the elevation, by means of a graduated arc and pointer attached to the carriage.

It is the time taken in this operation that determines the size of the squares into which the chart is divided. With the 40 yards squares the man with the range card is continuously reading out angles, when the ship that is being observed is moving with a speed of about eight knots per hour.

When the guns are at long intervals, each must have its own range card, but in casemated batteries with the guns close together, as many as four may be grouped, and use the same range card, without introducing too much error in the laying. A group should not be more than 120 feet long.

The zero line of the graduated arcs in the case of barbette guns has been, up to the present time, the right hand line of fire of the gun, the arc for each gun being graduated independently.

For casemated guns at short intervals it is the right hand line of fire of the battery, the graduations being continuous throughout. This allows of the guns being grouped in any way that may meet the requirements of the work. It has recently been decided that continuous graduation shall be adopted for all future batteries, whether casemate or barbette; and the zero line is to be the direction of the true north.

Position of observing stations.—The observers, in this system, are placed in small concealed buildings, outside the battery, so as to get a long base of some thousand yards or so, and to be clear of the smoke, the noise, and the enemy's projectiles.

Position of plotting room.—The plotting room in which is the chart with the electrically moved arms, should be in some secure place in the fort, where the officer commanding can have easy access to it. From this room the information obtained is sent down to the different range dials at the guns.

Telegraphic communications.—There must be telegraphic communication between the plotting room and each of the observing stations, and also telegraphic or speaking tube communication between the plotting room and the commanding officer's look-out station, for which some point in the fort must be chosen, and about which more is said in a later paragraph.

Wires.—4-core cables should be laid between the observing stations and the plotting room. Two wires are required for the position finding instruments, one for telegraphic communication with the commanding officer's look-out station, and another for communication with the plotting room.

A range dial requires 5 wires from the plotting room, but several can be in continuous circuit if wished. In the case of a battery with a straight face, where all the guns can see the same object, and where there is only one position finding instrument, there is no objection to all the range dials being in continuous circuit, but, otherwise, it is best to keep those of different groups independent, so that each group may have the information that is useful to it, and that the others may not be troubled to watch the dials to no purpose.

Size of observing stations.—The detached observing stations have each to contain an observer and a telegraphist with their instruments. The rooms may be 8 feet by 5 feet, or 8 feet by 8 feet, if convenient, and as much concealed as possible, consistently with the observer having a clear field of view from a long horizontal loophole.

Size of plotting room.—The plotting room has to contain a table with the chart, about 4 feet 6 inches by 3 feet 3 inches; a Morse telegraphic instrument; and instruments in connection with the range dials. Also three men; one of whom reads off the number and letter of the square indicated on the chart; another sends it down to the batteries; the third attends to the telegraphic instruments. A clear space is required around the table. A room about 15 feet square is large enough.

The commanding officer's look-out station had best be described after the other form of position finder, as it would be provided with one of the latter.

Depression position finder.—The other form of position finder is the depression position finder, which is, in principle, merely the depression range finder with an added contrivance for indicating on the chart the position of the object observed. This consists of an arm which traverses with the instrument, and an ingenious arrangement with a cord, actuated by the turning of the cylinder by which, as in the range finder, the telescope is raised and depressed, the cord causing a button to travel along the arm just mentioned, and to indicate on the chart the point on the water at which the telescope may be directed.

Advantage of depression over electric system.—From this description the chief point in which the depression system is superior to the electric is evident, namely, that each instrument is complete in itself, and gives the position on the chart, without the intervention of any plotting station. This removes a great cause of trouble and of error, as there is no necessity for explaining to two distant observers what object they are to direct on. With the depression system the observer cannot be altogether wrong if he follows an enemy's ship, although it may not be the one which the commanding officer wishes to fire at, but with the electric system unless the two observers follow the same vessel the indications on the chart are absolutely misleading.

Range charts and range dials.—The mode of communicating information to the guns by means of a chart divided into squares, by range dials and by range cards, is the same in the depression system as in the electric; but the numbers and letters are sent to the range dials direct from the detached observing stations, without passing through any plotting room.

A range dial in connection with those at the guns should be placed in the commanding officer's look-out station, so that he may know what information is being sent in; and he would of course be in telegraphic communication with the detached station.

There should be at least two detached observing stations, so as to guard against the chance of one being obscured by smoke, and each should be capable of communicating with the whole battery, but if they were both clear they would observe on different ships and send positions to different groups of guns.

Position of detached observing stations.—The detached stations may be in any convenient positions, not less than 80 feet above the water, though they should be higher if possible; and it is desirable, though not a necessity, that they should have a secure communication with the battery.

The detached station should be about eight feet by eight feet. It has to contain the position finder and chart, the instruments connected with the range dials, and a Morse instrument; also three men, an observer, a telegraphist, and a man to read the positions from the chart.

The arrangements are not settled yet in detail, but the instrument will certainly be worked by the observer through a hole in the roof, thus enabling the whole building to be sunk in the ground.

Wires.—As a rule a 7-core cable will be required from each transmitter in an observing station to each look-out station; viz:—4 wires to work the range dial, and 1 to set it to zero, a wire for a telegraph instrument, and one wire spare.

Commanding officer's look-out station.—The commanding officer's look-out station is an adjunct to a casemated battery, the importance of which has up to the present only received partial recognition, but which will have to be provided in a complete form in connection with position finding appliances. The commanding officer should be in a position to observe, in security if possible, all the water commanded by his battery; he should be able to give rapid and clear instructions to the observers in any position finding system that may be adopted, so as to be able to direct the fire with certainty on any vessel that he may think fit; and he must know what information they are sending in; he must also be in easy communication with the gun floor, and must be able to visit it at once if his presence be required.

He must have a proper attendance of at least one officer and one orderly.

These considerations have led to the preparation of a design for a commanding officer's look-out station, which is at present being executed with a view to a practical trial.

It consists of a room 15 feet long by 7 feet wide, placed on top of a casemated battery, partly sunk in the roof, protected in front and at the sides by a concrete slope, and with the roof formed of a 3 inch armour plate laid nearly flat. The rear is filled with wood framing and glass like a casemate front.

The commanding officer will stand in a recess in the front wall, making the room more than 7 feet wide at that point, and will look out through an opening in the roof, so that he need only be exposed from his eyes upwards; at the same opening would be worked a depression position finder, having its range chart in the room. This instrument would be used here whether the depression or the electric system were adopted for the detached observing stations, and under these circumstances may be employed even if it be as little as 40 feet above the water. This instrument gives the officer commanding the power of determining at once with considerable accuracy the square in which any vessel may be that he wishes to direct the observers to follow, and conversely it enables him to determine what vessels they are following. It may also be used for directing the fire of the guns, if not blocked by smoke.

In addition the room will contain range dials in connection with the detached observing stations, transmitting instruments for signalling the squares either to the detached observing stations or to the guns, Morse instruments for telegraphing to the former, speaking tubes communicating with the gun floor, and men for working all these appliances; that is, a man at the speaking tubes, a telegraphist and transmitter, a man to read the chart, an observer, the officer commanding, his orderly officer, and orderly.

Some of the details of the systems.—It is premature to give any detailed description of the fittings of any of these stations, as they are by no means finally settled yet. Still a few points may be mentioned. The detached observing stations must be concealed as far as possible by making up the exterior on the sea side to resemble some of the features of the surrounding country; at the same time plenty of light must be admitted at the back.

The electric wires must be buried several feet deep during war time, so as not to be injured by a chance shot. In the fort they should, if possible, be at once secure, and easy to be got at; the latter condition being the most important.

The range chart will be mounted on a slate slab, but it is not decided whether this will be horizontal or inclined against the wall.

The opening for the observer with the depression instrument should be of an approximately oval shape in plan, about four feet six inches long by three feet wide.

The various instruments will each take up about as much room as a Morse recorder.

In both the electric and depression systems, there should be some distinct point or points at known distances and bearings, by observing which the instruments can be checked and adjusted.

With the depression instrument, if there be any rise and fall of tide, there must be some means of continually adjusting the instrument to the correct height above the water level.

The best way of effecting this is to measure the exact distance to some object, such as a pile or the end of a pier, where the water-line is distinct. By observing this water-line with the instrument set to the range the proper adjustment for the height may be determined.

Survey for the range chart.—It remains to say a few words about the preparation of the range chart. This requires an extremely accurate survey, embracing the following points—the sites of the various position finding instruments at the observing stations, the pivots of the guns, their graduated arcs, and certain objects by which the instruments may be tested and adjusted.

The chart should be plotted on the scale of 12 inches to one mile; and it may be found advisable to survey the gun pivots on the scale of 10 feet to one inch, and then to reduce the plan to the smaller scale. The plotting must be done with very great care on paper mounted on a slate slab, and the chart for each instrument should be separately plotted without any tracing or transferring. When this has been done, and the squares of 40 yards side, as before mentioned, ruled in on any convenient meridian, and numbered and lettered, the range from each gun to the centre of each square visible to it has to be measured off, and the corresponding angle of elevation calculated, allowance being made for the height of the gun above the water level. Also the readings of the graduated arcs that will direct the guns they belong to on to the centre of each square must be determined.

This information is then made up into range cards for each gun.

The preparation of the range cards will probably fall to the lot of the Artillery; the surveys, of course, will be done by the Engineers.

It will be necessary to take every precaution to ensure accuracy in this survey; a small error would permanently misdirect the guns, and render the whole position finding system absolutely misleading. An error of a little more than $\frac{1}{4}^{\circ}$ will throw a gun off a square at 4,000 yards range.

The position finding systems just described are only applicable to important places, from the expenditure they involve, and the staff required to keep them up.

It is, however, to be hoped that some modification, either of the depression system or of the electric, may be devised, which, though not so complete as these, may be serviceable enough for the smaller places.

Précis on "Range and Position Finding."—A short account of the various systems of Range and Position Finding for coast batteries, in the forms in which they were tried, was issued to all stations in the spring of 1882, with $\frac{84}{\frac{W}{1989}}$, for general information. I would recommend any one taking an interest in the subject to read it, and also Captain Watkin's paper on "Range and Position Finding—Past and Present," delivered at the Royal United Service Institution, on June 17th 1881.

5. 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 its effects do not extend far. A 38-ton gun has been proved not to injure a counter-scarp gallery in front of it, although the ditch was narrow and shallow, and the counter-scarp therefore not far from the gun. I am not aware though that any one has been in the gallery when the gun was fired.

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 shewn by the fact that the fastenings all give way outwards.

I have known the iron bars securing the doors of shell recesses, which are $2\frac{1}{2}$ inches wide, and $\frac{1}{2}$ inch thick, bent from the effect of firing a 9-inch R.M.L. gun. This is an instance of what the blast may do, and shews 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 over-head 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.

6. SAFETY OF CARTRIDGES.

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, shewed 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 six feet without any other result than that the unexploded cartridge would be knocked down, and the case made hot enough to blister the paint.

This shewed 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.

Steps to be taken to secure the cartridge stores.—The next step was to determine what was necessary to be done to secure the cartridge stores from the effect of an explosion passing down the lift. Some old casemates at Eastbourne were altered to resemble magazines with lifts, lamp recesses, doors, &c., and various experiments took place, the results of which may be summed up as follows :—

160 lbs. 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, 160 lbs. 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 shewed that the provision of one trap-door in a lift is sufficient to prevent an explosion passing down it, for although the trap door will be open when the charge is going up, yet at that precise time no charge can be in the top of the lift, and an explosion taking place not in, but only near, the lift will not pass down it with sufficient violence to do harm.

For a description of the safety-trap proposed to be used in consequence of this experiment, see Lecture III., p. 115.

Effect of an explosion on the lamps.—Another point to be determined, was how the lamps were affected by the explosions. It was found that an overhead lamp inserted into a shaft from the gun floor was invariably put out; 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. P^2 was fired in the top of the lift with the trap up. 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. P^2 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.

Doorways to cartridge stores.—During the experiments, two doorways representing the entrances to magazines were closed, one by a wooden door, the other by a hinged rope mantlet; these were left ajar and were always shut by the action of the explosions, and were thus effectual in keeping out a good deal of the smoke, and most probably of the flame also. The effect was certainly sufficient to have made the difference of the lives of any men in the magazine chambers. It therefore appears advisable to insert swinging mantlets at cartridge store doors and at various points in magazine passages, so as to cut off and limit the effects of any explosion that may pass down the lifts. The mantlets would be stiffened with galvanised iron bars, and would be fitted with a weight or a spring to close them. See Lecture III. page 98.

The wooden door used in the experiment was broken by being violently slammed to, although it was strongly made.

Woodwork about lifts to be avoided.—It was found that the great blast of flame coming from the cartridges burnt in the open air set fire to the woodwork that it came in contact with; the action is so rapid that it seemed 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 a 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 extinguished, but the use of battens inside the lifts should be entirely abandoned.

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.

Various classes of works.—They 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 the 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.

They must contain bombproofs for the garrison, and some magazines, but the main magazine accomodation will be in the forts.

The main redoubts 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 works 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 works 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.

Trenches.—The trenches would 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 H.P. siege carriages, or will mount mortars or rifled howitzers, 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 reverse slopes of hills, the fire being directed by pickets; 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.

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. 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 it is pretty certain that the labour will not be thrown away.

Position of the temporary works.—The question may be now asked whether these temporary 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.

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 temporary works should be placed.

This may be best settled by a consideration, in the first place, of the advantages gained by permanently fortifying a place, as these advantages should of course, if possible, be retained, 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. The most powerful guns must be at first in the forts, and could at no time be moved far from them, as the way in which the defence can gain a superiority in artillery is that it can use weapons which need not be so mobile as those of the attack, and consequently may be heavier.

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 300 yards from the line of the forts.

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

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 a little 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 300 yards can only hold good 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 one 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.

8. CALCULATION OF GARRISONS.

It is necessary to calculate the garrisons of works, 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 designed 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 caponniers, 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.

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 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., 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.

Movable force.—Secondly, by adding a sufficient force to resist any attempt of the enemy to penetrate between the forts; an attempt which it is evident might be made, though I am not aware of such ever having been done.

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 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 has 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 here 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 really an open battle-field.

Large field force required.—It would probably be necessary 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, applies fairly to some of the new German fortresses, except that they usually have a nucleus of old works, and I believe 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.

For the construction of works in a second line, and in the front line before the investment, 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.

Amount of movable force.—This number is that which, as we have seen before, it is necessary to allow for fronts 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.

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. 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.

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 the 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 by mounting guns in them; for at the beginning of a siege the forts should be able to speak decidedly; later on many of 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 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. 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.

In the *R.E. Professonal Papers*, Occasional Papers Series, Vol. I. 1877, will be found a paper by me on the subject of the "Garrisons required for Modern Fortresses," treating of it in some respects more fully than here. A garrison, however, calculated according to the rules laid down in that paper, will be smaller than if calculated according to what has been written above. The difference arises from the different points of view from which the subject has been regarded. It is here looked at in a more abstract manner than in the paper written in 1877, when the actual numbers likely to be available for our garrisons were more particularly present to my mind.

9. EFFECT OF THE NATURE OF EARTH OR ROCK 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 for instance if it were very light and shaley.

Ashlar.—Then, if the stone is fit for ashlar, one will be able to make use of cut stone about the casemate fronts, entrances, and bombproofs, and in the lower parts of the disappearing gun pits; 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 I should prefer using 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.—Concrete 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.

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, etc., 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 one with material for concrete; it will be well to cover the parapet with loam to prevent stones flying.

Sand and clay.—Sand and clay are of course 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.

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.

In a rocky site where mining is not likely to be used by the enemy, counterscarp galleries may be used to flank the ditches.

On an earth site caponniers are somewhat preferable if the fort be liable to a close attack.

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 be easily cut and yet will stand of itself, it is easy to cut underground galleries of communication.

10. 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 you are 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 your usual basis.

Charts.—For a coast fortress, such as ours 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 land works, 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 you have learnt its features you will know the qualities of your 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 you 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 nowadays that it is only with the aid of a map, on not too large a scale, that you can bring before your mind simultaneously all the points bearing on the selection of the sites for your 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 you can 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.—You will be able 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 be only shelled from a distance.

In fact you will be able roughly to design the works in your 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 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 shewing details which are not wanted in the first stages of a design. 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 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 $\frac{1}{2500}$. 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 shewing 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, for every intersection of slopes, every turn in the whole plan, can be shewn on that scale, and the plan 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; you 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 you to see where you can fix permanent marks, showing your main laying out lines, so that they shall not be lost, and so that you can refer 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, you will have 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 design 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.

You will also be able to find out whether, before beginning work, any special arrangements will have to be made for water supply, for repair of roads, for the supply 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.

I need say no more about that, than that you must have some idea of the sort of work you are going to erect, in order that you may include enough land to contain it, with its glacis and approaches. If land is cheap—if land ever is cheap that is sold to the 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 should be from 15 to 25 feet above the level of the interior of the fort, the height depending on the nature of the rampart, whether solid or casemated. A crest line sketched round the hill can be converted into the proper polygonal form afterwards.

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 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.

Direction of faces.—The next thing is to lay out the front faces of the work, that is, those that are not exposed to enfilade fire; there is usually not much choice about this; and then to decide in what direction the Haxos or other casemates may safely look.

Arrangement of the guns.—Then settle the arrangement and number of the guns. They are the chief things in the fort, 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 will 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.—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 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, the avoidance of exposure to enfilade or reverse fire, and convenience of ammunition service.

It is difficult to protect a barbette battery from enfilade or reverse fire; 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, casemates should not be so arranged that a shot entering one of the ports could 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 battery the best way would be to arrange the guns in groups, with large masses of earth and masonry separating them, thus obtaining another advantage from this disposition, besides those before pointed out in Lecture VI., p. 189.

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 your 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 datum to which all the heights are referred.

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 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 judgement, 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, varying from $\frac{1}{18}$ 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.

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.

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 extravagancies 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 you can help it. 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.

11. WHAT FOREIGN NATIONS ARE DOING.

A few words on what other nations besides ourselves are doing in Permanent Fortification will be of interest.

FRANCE.

Coast works.—The French were doing absolutely nothing in the way of coast batteries when these lectures were comenced. They had guns mounted at points on the coast, but not of large calibre, and in old fashioned batteries without traverses or iron protection. They have now taken up this part of their defences, but I do not know the nature of their works, beyond the fact that they employ Gruson's cast-iron armour, concerning which, see p. 235.

Land defences.—On land it is different; there they have constructed vast works on their eastern frontier and round Paris. There it was of the first importance to them after the War of 1870-1, that they should be at once provided, not with fresh forts only but with fresh fortresses, and those on the largest scale. This necessity ruled the designs of the works which were put in hand, and which were arranged to be in fighting order in as short a time as possible, and completed in a permanent manner afterwards. To this end a section was chosen, which is especially adapted to rapid construction, viz., a broad ditch with a sloping counterscarp and detached escarp, a low front parapet, and a high interior cavalier under which are the casemates for the garrison.

This arrangement permits of the low exterior parapet being completed first, when the work is at once defensible as a strong field-work. Building the casemates, excavating the ditch to its full depth, and heaping up the cavalier battery can then be proceeded with at leisure.

The French in the first instance constructed their casemates and caponniers of wood, and erected a palisade fence for the detached escarp; they are now replacing this woodwork by masonry.

The arrangement that they were forced by circumstances to adopt does not seem altogether the best in the abstract, and very likely they would admit as much.

The high cavalier standing up in the middle of the work is much exposed to fire, and could hardly be expected to retain its guns uninjured for long. Moreover, it would catch shells intended for the lower battery, and cause them to burst back on the latter. On the other hand it is entirely independent of the ditch, so that it is less likely to be breached.

They appear as a rule to have no special positions for delivering curved fire from, unless it be from outside the forts, except that in some cases they have interior gun casemates, hidden from the outside.

The broad ditches with sloping counterscarps must expose the escarps and caponniers to be struck by curved fire, but this is now unavoidable; it necessitates, however, special care being given to the construction of the caponniers.

As regards the details of the works, the most noticeable feature is the way in which the guns are protected by traverses. There are never more than two guns together, and usually each one is by itself in a regular pit, with high traverses on each side. The guns are mounted, I believe, on high traversing platforms and carriages.

The main magazines are often outside the works in rear. Probably this disposition was adopted to allow of rapid execution.

The French are careful to clear the ground round their works of anything that might interfere with their fire.

For flanking the ditches they have adopted a novelty, in the shape of the Hotchkiss revolving cannon.

This is a machine gun of $1\frac{1}{2}$ inches calibre with 6 barrels revolving on a central spindle. The gun fires through an embrasure in a casemate wall which is only just large enough to admit the barrels without giving any room to traverse or elevate. For firing down ditches at a comparatively short range the necessary elevation can be given once for all when the gun is fixed, as well as the general direction. The necessary dispersion is given in the following manner. Each of the 6 barrels is rifled to a different twist, so that the projectiles, which are little case shot, are rotated with different degrees of rapidity on being fired. The effect of this is that the cones of dispersion of the bullets of the case fired from each barrel are different, and are so arranged that while one barrel spreads its missiles out at a sharp angle immediately on leaving the muzzle, another makes them keep nearly together up to the end of the ditch, the other barrels giving intermediate amounts of dispersion Therefore on operating the mechanism of the gun, the ditch is immediately automatically swept with case shot. The gun will fire about 30 shots per minute.

This appears to me too mechanical an arrangement to trust to in war; there is no adaptability about it, and it would be at once thrown out by any accident, such as a partial filling up of the ditch, or a little derangement of direction from a projectile striking the caponnier wall. The bullets too, from an $1\frac{1}{2}$ inch case shot are small ($1\frac{1}{2}$ oz.) and cannot have much penetrating power. Moreover, the guns are expensive, and require more care and attention than caponnier guns, as a rule, get.

I much prefer the S.B. B.L. gun which has been introduced into our service, see Lecture II., p. 59; it is strong, manageable, and cheap, and it fires much heavier balls than the Hotchkiss.

GERMANY.

Coast works.—The Germans have erected considerable coast defences along the shores of the Baltic and North Seas.

Gruson's cast iron armour.—Casemates.—They have made an extensive use of Gruson's cast-iron armour, both in the form of casemates and turrets. This armour is formed of large masses of iron very carefully cast and chilled on the face. The surfaces are all curved in order that a shot may glance on striking. The edges are planed so as to fit closely together, and contain a groove which is run with lead. The masses of metal are very large, some being 3 feet thick in the thickest parts, and 8 feet high by 8 feet wide; they weigh about 38 tons each. The roofs of the casemates are formed of cast iron beams, about 19 feet long and 5 feet wide.

This armour depends for its strength partly on its curved form and hard surface, which would cause shot to glance, and also on its thickness and massiveness which would prevent it falling in pieces, even if badly cracked. The cost is about the same as wrought iron armour of the same calculated strength.

I am not able to give any information as to the actual resisting power of this armour against heavy guns, as M. Gruson has not sent any to England for experiment No doubt it would prove to be strong, for great care is taken with its manufacture, but I cannot think it would be found superior to our own wrought iron plates. The latter will take a great deal of hammering without being much the worse for it, while the cast iron must get shattered in a few rounds; it will, though, resist a large number of rounds from guns which are not of great power. A Gruson battery is, however, a very workmanlike looking affair.

Turrets.—The Gruson turrets are dome-shaped, containing one or two guns each. They have no actual pivot, but have a large hole left underneath to allow of a fresh gun being mounted in case the one in the turret be disabled.

A fort on the Weser in which a row of turrets is placed, has a sloping escarp faced with granite, which is a very strong construction against shot.

Some of the German coast guns are mounted on A pivot racers, and fire *en barbette*. The guns are closer together than we should put them at the present day.

Land works.—The German type of fort differs materially from the French and from ours. It is shallow, with short flanks, and without a cavalier battery. It appears to be constructed more as a position for artillery for firing on the enemy's approaches, than as a work intended to hold a position.

Probably the Germans consider that with the large number of men they can always dispose of, they can count on having strong garrisons in their fortresses, and that there is consequently no chance of an enemy trying to penetrate between the forts. It therefore becomes unnecessary to provide for a heavy flanking fire from the forts, and they become only a means of providing bomb-proof cover and storage, and of giving a place for mounting heavier guns than can be used by a field army.

The forts are provided with detached escarp walls covered from projectiles falling with a drop of 18°.

The ditches are flanked by caponniers.

The works usually have a large traverse on the capital reaching across the fort.

In some of the works at Metz turrets are mounted, probably of Gruson cast iron.

Belgium.

The energies of Belgium are centred at Antwerp, which has been made into one of the strongest fortresses in Europe.

Coast works.—The river Scheldt is defended about four miles below Antwerp by two works, Fort Ste. Marie, and Fort Philippe. Fort Ste. Marie contains several cast iron casemates on Gruson's system, the guns in which fire down the river. On the other bank, at a bend, is Fort Philippe, with three turrets in a row.

Land works—The land defences of Antwerp have been often described; they consist of an inner continuous enceinte, with a citadel and an outer ring of forts.

The chief features are the broad wet ditches, the massive and commanding ramparts, and the powerful flanks.

The caponniers are long rows of casemates well covered with earth externally, and with embrasures intended to be shielded.

There are two particularly good points about them, which, however, require a good deal of room in execution; one is the massive head of earth which the caponniers have; the other is the internal parados of earth which would prevent a shot which might have entered an embrasure injuring any of the guns which look in the opposite direction.

The forts are furnished with large masonry keeps, which can no longer be so secure as they were against curved artillery fire. The low gorge batteries are well covered from the front, and would be useful for delivering indirect fire from, and for preventing any attempt to pass between the forts.

Casemated traverses and expense ammunition stores are built on the terrepleins.

The enceinte of Antwerp contains an arsenal, and also steam mills and other such appliances, so that there are all the means of making a long defence.

The detached forts at Antwerp are about 5,000 yards in advance of the enceinte; this is considered insufficient, and projects have been for a long time in hand for an extended line of works on the Nethe and the Duppel, which will carry the defence out about twice as far.

Turkey.

The Turks have a number of batteries on the Bosphorus and Dardanelles, but they were, and, I believe, still are, merely earthen batteries with the guns firing *en barbette.*

Their land forts are mere field works; Kars, which was supposed to be a permanent fortress, was not even so strong as Plevna. Some of the works had no ditches.

On the Tcheckmedje Lines, they are said to have thrown up a set of circular and elliptical works; the shape is not a bad one, if all idea of flanking the ditches be given up.

Russia.

The Russian works I do not know much about; they have invested in Gruson's cast iron armour; it is said that some of it is to go to Batoum. At Kronstadt they have a novelty in the shape of a 40-ton gun mounted on the disappearing principle something like the barbette guns of H.M.S. "Temeraire." It is a B.L. gun, and as it only just comes below the crest of the parapet there is not much protection gained.

A very large and powerful work has recently been constructed at Kertch to close the entrance into the Sea of Azov, but I believe it presents no novelties, although well organized and arranged.

ITALY.

The Italians have not as yet spent much money on fortifications.

They have however constructed works round Rome and at their great naval arsenal at Spezzia.

The forts round Rome are placed only on the main lines of approach, so as to check the advance of an investing army. They depend for security against assault on the walls of Aurelian.

At Spezzia they have constructed some groups of land works in an excessively rugged country running up as high as 1400 feet.

For the sea defences they have mounted one 100-ton gun and purpose putting up more.

The one already there is mounted *en barbette* in a pit with circular racers. Probably the rest will be made more secure.

AUSTRIA.

The Austrians propose getting some Gruson turrets, for coast works, but have not now much in hand.

CHINA.

The Chinese are building some heavy masonry works on the Canton river, but I do not know their details.

AMERICA.

The Americans are converting their cast iron S.B. guns into rifled, on Palliser's system, and are mounting them on their coast works, but these must be in much the same state as they were at the end of the Civil War.

AUSTRALIA.

The Australian Colonies are mounting long R.M.L. guns on a side loading system devised by Sir W. Armstrong's firm. See Lecture VI. page 182. It gives a good deal of security if the battery be not exposed to enfilade, but covers a good deal of ground, is difficult to make thoroughly safe except at a rather large cost, and it appears too liable to get out of order.

TABLE OF COST OF R.M.L. GUNS.

I. Nature of Gun.	II. Cost of Gun.	III. Cost of Gun with Platform, Carriage and Stores, and with 10 per cent. added to cover the cost of mounting, &c.		IV. Cost of 100 rounds of Ammunition.	V. Totals of III. and IV.
38-ton	£3,328	Casemate	£4,726	£850	£5,576
		Dwarf	£4,782		£5,632
25-ton	£2,110	Casemate	£3,031	£565	£3,596
		Dwarf	£3,101		£3,666
18-ton	£1,330	Casemate	£2,174	£440	£2,614
		Dwarf	£2,263		£2,703
12-ton	£910	Casemate	£1,525	£292	£1,817
		Dwarf	£1,586		£1,878
80-pr.	£175	Dwarf	£308*	£112	£420
64-pr.	£150	Dwarf	£198*	£95	£293

* Wooden carriage and platform.

VI. Nature of Gun.	VII. Authd. proportion of Rounds at Home.		VIII. Totals of III. and VII.		IX. Authd. proportion of Rounds Abroad.		X. Totals of III. and IX.	
	Number.	Cost.			Number.	Cost.		
38-ton	100	£850	Casemate	£5,576	250	£2,125	Casemate	£6,851
			Dwarf	£5,632			Dwarf	£6,907
25-ton	100	£565	Casemate	£3,596	250	£1,412	Casemate	£4,443
			Dwarf	£3,666			Dwarf	£4,513
18-tc	150	£661	Casemate	£2,835	300	£1,322	Casemate	£3,496
			Dwarf	£2,924			Dwarf	£3,585
12-ton	150	£438	Casemate	£1,963	300	£876	Casemate	£2,401
			Dwarf	£2,024			Dwarf	£2,462
80-pr.	100	£112	Dwarf	£420	250	£280	Dwarf	£588
64-pr.	0 0	£95	Dwarf	£293	250	£238	Dwarf	£436

NOTE.—Long R. B. L. guns will cost very little more than R. M. L. guns of the same weight, but the carriages and ammunition will be more expensive.

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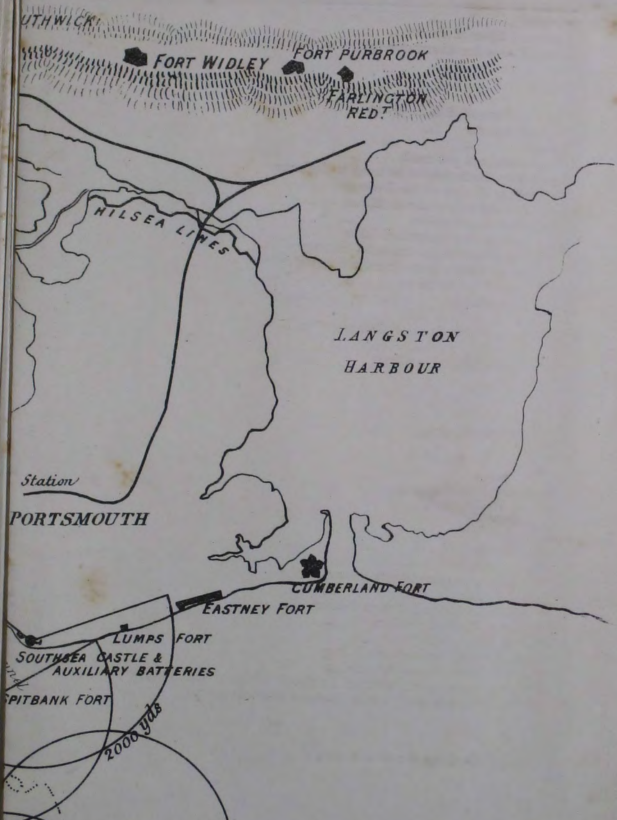
Plate I.



UTHWICK
FORT WIDLEY
FORT PURBROOK
FARLINGTON RED^T
HILSEA LINES
LANGSTON HARBOUR
Station
PORTSMOUTH
CUMBERLAND FORT
EASTNEY FORT
LUMPS FORT
SOUTHSEA CASTLE & AUXILIARY BATTERIES
SPITBANK FORT
2000 yds

PAPER II.

NOTES ON

ARMOURED DEFENCES,

BY

COLONEL T. INGLIS, C.B., R.E.

TABLE OF CONTENTS.

LIST OF PLATES

PAPER II.

NOTES ON ARMOURED DEFENCES.

By Colonel Inglis, C.B., R.E.

The subject of the following Paper appeared in the 'Proceedings of the Royal Artillery Institution,' Volume XI., No. 5, 1881, and was intended as a sketch of an hour's lecture delivered at Woolwich early in 1880.

The audience on that occasion was one upon which I could not think of inflicting much engineering detail, and as, besides, a considerable time has now elapsed since the lecture was first prepared, I have some misgivings as to its fitness to appear in our Corps volume, more especially as much of it is in substance a mere repetition of what I have written in previous Papers.

However, with the object of making it serve at least as an index to former contributions on the subject of Iron Fortifications, and to other sources of information connected therewith, I now add such references on each page as I think will help any officer who may wish to become more acquainted with particular parts of the subject, and in order to complete some of the information to a more recent date I have added a few observations in the form of a postscript. The original text has been but slightly altered, and two plates have been added.

Necessity for use of Armour.

Long before the general adoption of rifled cannon, it was a well recognised fact that the materials then in use for works of fortification were not a match for the guns which ships could carry.

Accordingly, we find that early in this century experiments were made with iron-cased walls at Woolwich, not to mention others made in much more remote times.*

* *R. E. Professional Papers* (Second Series), vol. xi., p. 189; and *First Report of Special Committee on Iron*, 1862, App. 1.

In 1853, extensive trials were made in the United States with smooth-bore guns against masonry structures having in them embrasures strengthened with iron and other materials.*

In 1855, the French employed three iron-cased floating batteries in the allied attack upon Kinburn, and, before peace was made with Russia, England also had iron-clad batteries afloat.

In 1856, iron plates were tried, both in this country and in France, against smooth-bore guns, and, in 1859, a shield for an embrasure, composed of massive iron bars, was tested at Portsmouth for Sir J. Burgoyne, by the fire of 68-pr. service guns; and besides many other trials of smooth-bores against iron about that time, in 1858, two armoured floating batteries were experimented upon at Portsmouth, by 62-prs. and 68-prs.†

The fact is, that it was nothing but the vagueness of the fire, and the rapid loss of velocity in the projectiles, of smooth-bore guns, that allowed our works and ships to escape as well as they did in former times. And this applies at least as much to the defences of other countries as to our own.

In this view, therefore, it is not surprising that, when guns of good range and precision came to be introduced, some great change in the mode of defence should have taken place.

But it has been urged that the mere fact of the old walls of our works having been found insufficient for the altered fire of artillery should not have condemned the material of which they were composed. If walls of 5 ft. or 10 ft. thickness were not strong enough, they could have been made 20 or 30 ft. thick, or more if necessary; and if masonry would not do, earth or concrete, or something else in large quantities, might have been used.

Well, to a great extent, this is really what has been done generally in works of fortification; but in forts for coast and river defence, which are the only works liable to the fire of the heaviest ordnance, a large addition of mass is altogether impracticable.

In any case, the formation of an efficient embrasure in a very thick parapet involves great difficulties; but in a work exposed to the fire of heavy ships' guns, the strengthening, which becomes necessary in the neighbourhood of the embrasure, involves a treatment which altogether alters the character of the work. The main reason, however, why the necessary strength cannot be gained in coast batteries by multiplying the thickness of the parapets, is that in the great majority

* *R. E. Professional Papers* (Second Series), vol. viii., Paper i.; and vol. xi., p. 190

† *Ibid.*, vol. xi., pp. 191–3.

of these works the character of the site practically precludes it. For instance, in the case of a fort at sea, it would be obviously out of the question to bring up foundations for an earthwork, or for a work having very thick parapets of other materials; and this difficulty holds good, with a difference only of degree, in most of the sites selected for our coast defence works.

Scope of Subject dealt with.

The question of strengthening inland defences by means of a partial use of armour is one that deserves great consideration, and, for my part, I believe that almost any fortress could be rendered practically impregnable, by the judicious use of iron or steel, at no very great additional expense; but I should be attempting too much if I were to introduce these topics into this Paper. I therefore propose to confine myself on this occasion entirely to works of coast defence, which are adapted to heavy guns firing through iron embrasures, or ports as they are now called—that is to say, to protected guns mounted on carriages and platforms of the ordinary type.

The general character of these works has been, from time to time, determined by the highest authorities, and therefore it becomes obviously my part, as it certainly is my wish, to avoid entering into any discussion as to the merits of the principle on which the guns have been mounted as compared with other methods which have been advocated.

I propose, broadly, to divide the subject under three heads; that is—

1st. To trace, briefly, the experimental stages through which the question of iron defences has passed.

2nd. To give some account of the materials used in these defences, and of their manufacture.

3rd. To describe, as far as time will allow, some of the principal iron works which we have set up for the defence of our naval arsenals and ports at home, and of our fortresses abroad.

I.—THE EXPERIMENTAL STAGES.

And I may say at once that the few early experiments to which I shall refer possess something more than a mere historical interest, because in them is to be found a warrant for every step we have taken in working out a system of iron fortification. Every point, down to those of the nicest detail, has been based on experimental results. I am sure those officers who have watched the experiments at Shoeburyness and elsewhere, will bear me out in saying that in no subject

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Early Experiments with Land Service and Ships' Targets.*

Starting then with events of rather more than twenty-one years ago, I may say that the first experiment in which rifled ordnance was used in this, or perhaps any, country against armour, took place at Portsmouth, in the latter part of 1858, when a Whitworth 68-pr., of 5 to $5\frac{1}{2}$-in. hexagonal bore, was fired at 4-in. plates attached to the side of H.M.S. 'Alfred,' and cast-iron shot 12·7 in. long, at 400 yds., indented the plates a little more than an inch deep; a wrought-iron shot 11·7 in. long, at 450 yds., passed through both plate and the ship's side.†

The first time that a rifled gun was fired at armour for land works, was in 1860, when an 80-pr. Armstrong gun fired wrought-iron flat-headed shot, and a 40-pr. fired cast-iron shot, at two iron embrasures (8 in. and 10 in. thick) fixed in a masonry work at Shoeburyness. This trial brought out the advantages arising from the use of iron for strengthening works, and the disadvantage of having splayed sides in an iron embrasure.‡

From that time experiments against armour followed each other rapidly.

In 1861, comparative trials were made between wrought-iron armour plates backed with rigid materials, such as cast iron and granite, and similar plates backed with timber, cork, indiarubber, layers of wire, and other substances. From these it was gathered that while the hard materials improved the resisting power of the armour, they led to its being more injured by cracking and to the giving way of fastenings.§

Other trials were made with wrought-iron plates inclined to the horizon at various angles, from which it was concluded that a mass of armour placed upright will offer as much resistance as the same

* For the bulk of the early experiments up to (say) the end of year 1860, see *First Report of Special Committee on Iron*, 1862; and *R. E. Professional Papers*, vol. xi., Paper xiii., pp. 184–97; also early part of *Notes of Lectures on Iron Fortifications*, Chatham, 1875.

† *First Report of Special Committee on Iron*, 1862, App. 9, p. 169.

‡ *R. E. Professional Papers*, vol. xi., pp. 195–7; *Report of Ordnance Select Committee*, quoted in *First Report of Special Committee on Iron*, 1862, App. 26; *see* also App. 43.

§ *First Report of Special Committee on Iron*, 1862, p. xxi.; App. 33, p. 226; *R. E. Professional Papers*, vol. xi., p. 201.

mass disposed at any inclination so as to cover the same vertical area.*

Even *wool* was experimented upon as to its power of resisting cannon shot, and I need scarcely say that it failed signally.†

Next, some shields, 6 in. and 10 in. thick, composed mainly of boiler plates $\frac{5}{8}$ in. thick, riveted and screwed together, gave very indifferent results; ‡ and two other heavier casemate shields, of very opposite construction, made of massive slabs of rolled iron, laid one in front of the other, and crossing at right angles, with lead between them, were tried in 1862–3, with good results.§

Of targets representing portions of ships' sides, I find I cannot omit all mention, because so much of the experience gained from them has been useful to our service.

In the 'Warrior' target, composed of $4\frac{1}{2}$ in. of rolled iron plates on 17 in. of wood, backed by a thin iron skin, we saw the advantage of timber backing, the weakness of joints in armour, and the disadvantage of joining armour plates to each other by means of tongues and grooves on their edges. In other of these ships' targets the question of providing a compound backing of wood and iron instead of wood alone was practically solved in favour of the former, and the disadvantage of doing away with all wood in the backing was also proved.‖

During the period of which I have now been speaking—that is up to 1863—the heaviest gun used in experiment was a $10\frac{1}{2}$-in. rifled gun, throwing a cylindrical shot of about 300 lbs., with a muzzle velocity of about 1,320 f.s.¶ There was also a 7-in. Whitworth (130-pr.) and a large 13-in. smooth-bore Horsfall gun. But shortly afterwards a

* *First Report of Special Committee on Iron*, 1862, p. xvi., and App. 37, p. 236; *R. E. Professional Papers*, vol. xi., p. 199.

† *Fourth Report of Special Committee on Iron*, 1864, App. 19, p. 90.

‡ *First Report of Special Committee on Iron*, 1862, p. xx., and App. 44, 45.

§ *Second Report of Special Committee on Iron*, 1862, pp. viii. and ix., and App. 33, and 34; *Third Report of Special Committee on Iron*, 1863, p. xii., App. 203; *R. E. Professional Papers*, vol. xi., p. 202; and vol. xii., pp. 132–6.

‖ For advantage of timber backing, see *First Report of Special Committee on Iron*, 1862, par. 53 and App. 41; and *Second Report*, pars. 14–16 and App. 26, 28, and 31. For weakness of joints, see *First Report* of same Committee, par. 32. For disadvantage of tongues and grooves, see *First Report* of same Committee, pars. 38 and 50. For the advantage of compound backing, see *Third Report* of same Committee, pars. 16 and 18.

¶ In 1863 the Special Committee on Iron considered that, for the successful attack of armour, shot should have a striking velocity of at least 1,000 feet per second.

23-ton gun of 13·3-in. calibre, capable of piercing a ship's side, stronger than that of the 'Warrior,' at 2 miles range, with a shot of 600 lbs., called for a corresponding advance in the strength of armoured structures.

Consequently H.M.S. 'Hercules' was protected with 9-in. armour at her water-line; and a target representing her at this part, with a very massive backing of teak and iron stringers, ribs, and skin, afforded effective resistance to the gun I have referred to at 700 yds. range, and would have done so at much shorter ranges. This trial showed the advantage of giving depth or thickness to shot-resisting structures.*

A method of holding on armour plates by continuous irons turned over their edges instead of by bolts was also tried, but there were objections to it.†

Turning again more particularly to the protection of land works, the following experience was gained about this time—that is, in 1865.

Two complete masonry casemates with ports in iron shields were built at Shoeburyness. The masonry was 14 ft. thick, consisting, generally, of a face of 6 to 8 ft. of stone with brickwork behind it, and the side walls and vaulting of the casemates were of brick. The shield of one was a compound structure 12 ft. long, 8 ft. high, and, altogether, 21 in. thick (including 7 in. of wood); that of the other was made out of a solid rolled iron plate, 7 ft. high, 6 ft. wide, and $13\frac{1}{2}$ in. thick. After the mounting, working, and firing of a 23-ton and a 12-ton gun in the casemates, as well as on the roofs, had proved the work to be suitable in arrangement for such guns, the front of the work was attacked by a battery of 7-in., 8-in., 9·22-in., and 10-in. guns, at ranges of 600 and 1,000 yds., firing steel and cast-iron shot, some with hemispherical, and some with elliptical heads.

The general result of this trial was that after 33 hits the work began to become untenable, after 54 hits its fire would have been virtually silenced, and after 86 hits, of which 22 were on iron, the masonry front was destroyed, but the shields still afforded a fair amount of protection.

The aggregate of all the blows delivered came to 200,000 ft. tons, of which 52,000 were on iron.

The issue of this experiment was of the utmost importance to the service, because on it was based the decisions (1) that our most advanced and important sea forts should be protected by walls con-

* For the trials of 'Hercules' target, see *R. E. Professional Papers*, vol. xiv., p. 164, and vol. xvi., p. 165.

† *Second Report of Special Committee on Iron*, par. 15, and App. 31.

sisting wholly of iron, and (2) that for other coast batteries masonry might be used, but that every gun casemate of these should have a shield affording protection against fire equal, *at least*, to that of its own gun.*

Chilled Cast-iron Projectiles Adopted.

Amongst many other trials that took place about this time were those which brought out the excellent qualities of chilled cast iron for battering projectiles, as proposed by Capt. (afterwards Sir W.) Palliser, and also the advantages of the pointed (ogival) over the blunt (hemispherical) head. For these experiments iron armour, placed both directly and obliquely to the line of fire, was used. Chilled iron, in consequence of these results, almost entirely superseded steel for battering projectiles, for a time at least. As this question, however, has been recently reopened, it will be briefly noticed later on in this Paper.†

Early Trials of Steel and Compound Plates.

Next in order came a series of trials of plates of steel, and of steel and iron combined; some were of thin layers of steel and iron welded together, others of sandwiches of steel between rolled iron, others of faces of steel welded to iron, and others of steel and iron in reverse order to this; but none of these competed successfully with a simple soft rolled iron plate in resisting chilled iron shot; some plates made entirely of steel were tried about this time, as they had been also years before, but none of them stood at all well. The difficulty of treating steel in large masses, and especially of welding these masses of steel and iron together, had evidently not been mastered up to this time.‡

Evidence of Thickly Armoured Walls being necessary.

In consequence of the growing powers of battering ordnance it now became evident that our land works would require walls of consider-

* *R. E. Professional Papers*, vol. xviii., pp. 177–90.

† For experiments leading to the introduction of chilled cast-iron projectiles, *see* particularly *R. E. Professional Papers*, vol. xiii., Paper xvi.; vol. xiv., Paper xi.; and vol. xvi., Paper xii. In the summer of 1866, iron shot cast in chill were introduced into the service, and the manufacture of steel projectiles ceased.

‡ For the particular trials in 1867, here referred to, see *R. E. Professional Papers*, vol. xvi., pp. 138–40; but very much earlier combinations of steel and wrought iron were tried at Shoeburyness—see *First Report of Special Committee on Iron*, 1862.

able thicknesses of armour; but there were two main reasons why very thick armour plates should not be used in them. In the first place, the manufacture of a very thick plate is not so complete as that of one of moderate thickness, or at least to make it as complete would involve an enormous increase of cost in plant and manufacture; and, next, the thicker the plates the deeper the joints must be, and therefore the more points of undue weakness will the armour present.

It therefore became important to see whether the required protection could not be gained without the use of very thick plates.

Against doing this was the prevailing opinion, based chiefly on theoretical considerations, that a single plate of given thickness would offer something like twice the combined resistance of two plates each of half that thickness, or about three times the resistance of three plates making up the same total thickness, and so on.

This view was entirely disputed by those who had to deal with these questions officially, but it became our business to prove its fallacy.

This was done under the following circumstances:

Plate-upon-plate System Introduced.

In 1867, a total thickness of 7 in. of iron disposed in one solid plate, in two plates of $3\frac{1}{2}$ in., and in three equal thicknesses, instead of giving resistances of about 100, 50, and 33, gave effects more nearly as 100, 95, and 88, respectively.*

Next, a 10-in. plate failed to stop a shot which was stopped by two 5-in. plates, and another 10-in. plate bore out this result.†

Again, in a comparison between a solid 15-in. plate and a wall made up of three 5-in. plates, the result was that, although the solid plate gave a somewhat better resistance to a single blow, the three-plate structure stood repeated blows better than the other.‡

Also, in 1871, two targets representing portions of the walls of ships' turrets were tried at Shoeburyness. The one was protected by single 14-in. plates, the other by two thicknesses of armour, 8 in. and 6 in. respectively, with 9 in. of timber between them. In other respects the targets were similar. After receiving the same amount of battering, the armour of both was taken off, and the effect upon the inner skin of the two-plate target was unmistakably less than that on the single-plate structure.§

* *R. E. Professional Papers*, vol. xvi., pp. 140–42. † *Ibid.*, vol. xvii., pp. 199–202. ‡ *Ibid.*, vol. xvii., pp. 203–6. § *Ibid.*, vol. xx., pp. 49–62.

It may also be mentioned that, more recently still, a structure composed of three thicknesses of $6\frac{1}{2}$ in. of iron proved rather superior to a solid $16\frac{1}{2}$-in. plate in stopping the 818-lb. shot of the service 38-ton gun, striking with a velocity of about 1,415 f.s.*

In thus dealing with this subject it must not be supposed that the formation of iron walls made up of a number of thin plates was ever advocated by us. The trial of the boiler-plate targets, already mentioned, for ever disposed of that kind of construction.†

Surfaces of Plates should not be in Contact.

Also, it should be mentioned that the above trials of the plate-upon-plate system showed plainly that the most satisfactory results were not obtained when the surfaces of the armour were in contact, but that, on the contrary, some thickness of a softer and more elastic material between the plates was necessary to prevent their breaking under heavy blows.

Best Spacing between Plates.

To settle the best proportions, quantity, and best nature of material to be interposed between armour plates, a series of careful experiments was set on foot, and the result was that an uniform spacing of about 5 in. (to be slightly modified under certain circumstances) between the different plates in all structures was decided upon; and also, although an iron concrete, made by working up together cast-iron borings, asphalte, bitumen, and pitch, gave the best result, mainly on account of its great weight, yet brickwork in asphalte, Portland cement concrete, and hard wood, proved so satisfactory that these materials have been adopted, as circumstances required, in all our armoured walls.‡

It may be well to mention here a very remarkable result that was obtained in the course of the early trials with plate-upon-plate structures.

Void Spaces between Armour Plates.

When void spaces were left between the plates of these structures, it was found that the heads of the Palliser shells collapsed completely under the work they had to do in penetrating them, and, naturally, the effect produced upon the target was thereby very much reduced.

* *R. E. Professional Papers*, vol. i. (Occasional Series), pp. 3–5, and 222–5. *See* also pp. 73–5 of same vol.

† *See* p. 257 above.

‡ *R. E. Professional Papers*, vol. xviii., pp. 265–8, and 268–73. Targets composed of two 5-in. armour plates with solid lead about 5 in. thick between them were tried at Shoeburyness in 1871 with very promising results.

In one case a chilled shot from the 38-ton gun which was capable of piercing $19\frac{1}{2}$ in. of armour, was found sticking in a finely divided state against a 10-in. plate, after having passed through only a 4-in. plate a few feet in front of it; and on another occasion, a $4\frac{1}{2}$-in. plate, set up 18 in. in front of a masonry wall, with a void space between them, so far reduced the effect of a chilled cast-iron projectile from the 38-ton gun, at 50 yds., that it broke up on first striking the granite, and was afterwards dug out in pieces at a depth of only about 3 ft. 6 in. from the original front of the masonry.

Repeated and well-pronounced instances of this utter destruction of chilled projectiles from this cause have been gained and carefully investigated, with a view to turning the principle to some account in defence works; but partly on account of certain difficulties of detail, and mainly on account of the action not being produced on steel projectiles, the idea of using void spacing in practice has been nearly given up.*

Perforation of a Plate-upon-plate Structure Compared with that of a Solid Plate.

To explain, to some extent, the way in which a well-constructed plate-upon-plate wall offers resistance to a shot, I have had a diagram (*Plate* I.) prepared, from which it will be seen that each plate does not act independently of the other, but that by the back moulds of each one being forced against that next behind it a continuous resistance is offered to the shot during the whole of its passage through the mass. Of course, to get the full effect, the several plates must be well held together. To help comparison, the diagram shows also a shot in the act of piercing a single plate.

It may be well here to mention that our plate-upon-plate construction is, perhaps, more than any other, proof against what is called 'racking action'—that is, the effect of heavy shot striking at comparatively low velocities.

The next trials on a large scale, which influenced our proceedings to an important extent, were those of 1868, at Shoeburyness.

Experimental Casemate representing Plymouth Breakwater Fort.

In these, a casemate, having a front of 22 ft. × 14 ft., representing a portion of the iron fort which was then in course of construction for

* *R. E. Professional Papers*, vol. xix., pp. 106 and 107; vol. i. (Occasional Series), pp. 5, 75, and 225; and vol. ii. (Occasional Series), pp. 196–8, in which latter observe that steel projectiles successfully attacked void spaced targets of iron armour even when the front plates were inclined at a considerable angle to the line of fire.

the position behind Plymouth Breakwater Fort, stood 37 rounds from the 12-in. gun of 25 tons, charge 76 lbs. pellet powder; the 10-in. gun of 18 tons, charge 60 lbs. R.L.G.; and the 15-in. Rodman gun of 19 tons, charge 100 lbs. American (equivalent to $83\frac{1}{4}$ lbs. English) powder, at 200 yds. range; and, although it was of course considerably damaged by this fire, it was, at the end of it, pronounced to be defensible. This trial led to some important additions being made to the front wall of the fort itself, as it went on.

The roof also of this casemate was tested by the fire of 13-in. mortars, at 1,000 yds., but they proved quite powerless against it. Only a few shell, however, struck it out of nearly 300 rounds.*

Cellular Iron-fronted Casemate.

Adjoining this casemate was another, embodying several kinds of cellular construction in its iron front, with the object of comparing the resistance of moderately thick solid plates with that of thinner front plates supported by cellular compound backing; but in no instance did the latter construction prove itself superior to the other. This result was borne out by the trial of another shield in 1868. The support given to armour by massive piers of masonry and concrete, cased in thick boiler-plate, proved very satisfactory.†

Armour Bolts.

It may be well here to notice briefly the matter of holding on armour plates, on which so much of course depends, and I may begin by saying that of the innumerable contrivances for this object, nothing has been found equal to that of a simple screwed wrought-iron bolt fitted with nuts.

The steps by which the present pattern of armour bolt for fortifications has been arrived at may be thus described:

At first, a bolt with a V-shaped screw thread was used, but, in the early stages of our trials, a shallow round-cut thread was substituted for this with great advantage. Also a gradual and slight cone was adopted in lieu of the abrupt and spreading cone used at first in the heads of these bolts.‡

Next, Sir W. Palliser's valuable suggestion that part of the shank

* Extracts from *Reports of O. S. C.*, 1868, vol. vi., part 3, pp. 292–310, and 313–17. *R. E. Professional Papers*, vol. xviii., pp. 201–31.

† Extracts from *Reports of O. S. C.*, 1868, vol. vi., part 3, pp. 322–38. *R. E. Professional Papers*, vol. xviii., pp. 232–51.

‡ For early trials see *Reports of Special Committee on Iron*, and *R. E. Professional Papers*, vol. xiii., p. 135.

or stem of an armour bolt should be reduced to the lesser diameter of the thread, led to an immense improvement, and this has been since extended to the whole length of the stem, leaving the thread a plus or raised thread, thus facilitating the extension of the material of the bolt throughout its whole length instead of locally in short lengths.*

Then Captain English proposed, first, the rounding of the bearing surface of a common hexagon nut, and, afterwards, the use of a spherical nut seated in a cup-shaped hole in the armour, or in a special cupped washer; with these improvements, and that of the enlargement of the holes through which the bolt has to pass (all of which have for their object the relief of the bolt from cross strains, and the insertion of a due proportion of elastic material to be squeezed when the bolt is put under tension), all difficulties with bolts have disappeared, and instead of their being sources of weakness, they really, in most cases, give assistance to the armour.

We have had 3-in. armour bolts of our present pattern, and of moderate length, which only broke at the 7th blow from a ton monkey falling 30 ft., the diameter of the fractured part showing a reduction of 50 per cent., and the greatest extension of any part being from 1 in. to 2 in.; while the bolts made for our early trials would not stand one of these blows, and broke off quite short, notwithstanding that the iron, in a test machine, had proved ductile and strong. I may say that, with these excellent results, we have been contented with wrought-iron bolts, and have not run the risk of failure with steel bolts.

The special washers are of the following make:

Coil Washer described.

First, a circular washer is made by coiling and welding a bar $1\frac{1}{4}$ in. by $\frac{1}{2}$ in., and this is cupped to suit the spherical nut of the bolt. To strengthen this part, an outer coil of unwelded bar of about the same section is screwed round it: as this outer coil has to expand after the inner coil may have given way, and, as in doing so, it would naturally unwind itself and open out, this tendency to separation has been met by making the thread, by which this outer coil is screwed on to the

* For later trials see *R. E. Professional Papers*, vol. xvi., p. 135; and the experiments resulting from the trial of the Gibraltar shield in *R. E. Professional Papers*, vol. xviii., pp. 191–200; and various other experiments in *R. E. Professional Papers*, vol. xvii., Paper xv.; vol. xviii., Paper xiii.; vol. xix., Paper xii. Also Lieut. (now Capt.) English's 'Calculations of the Pressure produced by a Falling Weight in our Armour Bolt-testing Apparatus,' see *R. E. Professional Papers*, vol. xviii., Paper x.; and see also brief mention of this subject at pp. 3 and 4, *Notes of Lectures on Iron Fortifications*, Chatham, 1875.

inner, of quicker pitch than that of its own coils, and thus, as it unwinds, it actually becomes more and more tightly squeezed together.*

A diagram (*Plate* II.) of a bolt, completely equipped, is given.

Hammered Plates given up.

I must just mention here that, in 1868, a thick wrought-iron plate made by forging under the hammer, proved much inferior to a plate made by rolling, and as there were other disadvantages in the former method of manufacture, it has been entirely superseded by rolling.†

Casemate Shield of 1870.

All other trials of this period‡ may now be passed over until we come to that of the casemate shield, set up at Shoeburyness in 1870, which embodied all the experience that we had gained from the previous 12 years of experiment.

The guns used were the 12-in. of 25 tons, the 10-in. of 18 tons, the 9-in. Whitworth gun of 14½ tons, and the 15-in. Rodman of 19 tons, at 200 yds.; some rounds were fired obliquely, but most of them were fired direct at the face of the shield.

The shield, which presented a front of 12 ft. by 8 ft., received 17 blows, equivalent to 90,000 ft. tons, and, except in one or two matters of detail, which were susceptible of easy improvement, it stood the trial remarkably well, and proved that it possessed a great margin of strength for these, and even more powerful, guns.§

35-ton Gun at Plate-upon-plate Target.

In 1872, a plate-upon-plate target, representing 17 in. of armour altogether, stopped a Palliser shot fired direct at it from the 35-ton 12-in. gun with 110 lbs. of P. powder, and a similar target with 13 in. of armour stopped a shot from the same gun, striking it at an angle of 60° with its face.‖

* For a somewhat more full description of the construction of a coil washer, see *R. E. Professional Papers*, vol. xviii., pp. 268 and 269, or p. 10 of *Notes of Lectures on Iron Fortifications*, Chatham, 1875.

† See *Extracts from Reports of Ordnance Select Committee*, vol. vi., part iii., pp. 297 and 306; *R. E. Professional Papers*, vol. xvii., p. 205; and p. 7 of *Notes of Lectures on Iron Fortifications*, Chatham, 1875.

‡ For experiments in 1869, see *R. E. Professional Papers*, vol. xviii., pp.265–79.

§ *R. E. Professional Papers*, vol. xix., pp. 93–106; Extracts from *Reports of Dept. of Dir. of Art.*, vol. viii., part. i., pp. 47–52; and *Notes of Lectures on Iron Fortifications*, Chatham, 1875, pp. 12 and 13.

‖ *R. E. Professional Papers*, vol. xxi., pp. 130–32; and *Extracts from Reports of Dept. of Dir. of Art.*, vol. x., part. iii., pp. 173–75.

Turret Trials.

As the turret is now an important feature in all projects for coast defence, and will, I venture to say, maintain its prominence, I cannot omit it altogether in this summary of trials.

In 1861, the cupola of the 'Trusty' was tried off Sheerness. It was in the form of a truncated cone, covered with $4\frac{1}{2}$ in. of armour, and resisted fairly well the guns of those days. The cupola was not damaged in its machinery throughout the trial.*

Next, in 1866, one of the turrets of the 'Royal Sovereign,' carrying armour in thickness from $5\frac{1}{2}$ to 10 in., was tried at Spithead, with the $12\frac{1}{2}$-ton guns of H.M.S. 'Bellerophon.' The turret was a good deal injured, but the turning machinery remained in working order.†

In 1872, the turret of the 'Glatton' was tried, at Portland, with the fire of a 12-in. 25-ton gun of H.M.S. 'Hotspur,' at 200 yds. range. The armour was 14 in. thick, and it received two Palliser shot, fired with 85-lb. charges, one of which grazed first on the glacis. There was some damage done inside the turret, but the goat, rabbit, and fowl, which had been placed inside, were unharmed, and the turret turned freely after the trial.‡

Ships' Decks.

In 1870–1–2, some lengthened trials were made with shot and shell impinging upon ships' decks, which gave some decided results, namely, that a 13-in. mortar shell, at 4,200 yds. range, would go easily through a strong ship's deck covered with $1\frac{1}{2}$-in. plating and $4\frac{1}{2}$-in. wood planking, and that at 2,800 yds. it would go through it if covered with 1-in. plating; that 9-in. *live shell* from the 12-ton gun striking at an angle of 8° is too much for a similar deck covered with $1\frac{1}{2}$-in. plating at short range, but the same deck will just turn a 9-in. *shot* at the same angle. Also, that a strong deck covered with 3-in. plating and 4 in. of oak, was only just proof against 10-in. shells fired with battering charges from the 18-ton gun, and striking at an angle of 10°.§

* *First Report of Special Committee on Iron*, 1862, p. 185; *R. E. Professional Papers*, vol. xi., p. 200.

† *R. E. Professional Papers*, vol. xxi., p. 133.

‡ *Ibid.*, vol. xxi., pp. 134-37; *Journal of Royal United Service Institution*, 1873, vol. xvii., No. lxxii., p. 294.

§ *R. E. Professional Papers*, vol. xix., pp. 107 and 108; vol. xx., pp. 46 and 47, vol. xxi., pp. 125–9. Also *Extracts from Proceedings of Department of Director of Artillery*, vol. viii., pp. 123 and 209.

I venture to suggest that more information is required under this head, as regards the effect of later and heavier guns.*

A space must now be devoted to the experimental results of the more recent times.

LATER EXPERIENCE AS TO THE PERFORATING POWERS OF GUNS.

Without wishing to promote field guns into the ranks of armour-piercing ordnance, I may just mention here that the new 13-pr. M.L. gun has, quite lately, proved itself capable of piercing a $4\frac{1}{2}$-in. iron plate with a special solid chilled iron shot, firing its service charge at short range—say, 100 yds.†

The rule, that roughly held good a few years back, that battering guns could not, at the shortest range, do more than pierce iron armour plates equal in thickness to their own calibre, has been quite upset in the last year or two by practice from the new long guns with bores of 23 and more calibres in length. Thus, a 6-in. gun of less than 4 tons weight, and an 8-in. gun of less than 12 tons, have pierced within an inch of double their calibre in thickness of solid iron plate; and calculations tend to show that the projected long B.L. guns of 9·2 in. of 18 tons, the 10·4-in. of 26 tons, and the 12-in. of 43 tons weight, will achieve fully as much as this, if they are successful in other respects.

Speaking generally, the service guns were always capable of doing somewhat more than is indicated by the old rule above mentioned, and if, with the improved powders of the present day, their charges can with safety be increased to the extent which, I believe, has been proposed for them—as, for instance, 90 lbs. P^2 for the 10-in. 18-ton gun, 110 lbs. P^2 for the 11-in. 25-ton gun, and 160 lbs. P^2 for the $12\frac{1}{2}$-in. 38-ton gun—then these guns will be nearly, if not quite, able to pierce, at short range, a thickness of solid iron equal to $1\frac{1}{2}$ times their calibre.‡

While upon this subject, I may say that no attempt has been made in late years to determine the *law* of the resistance of armour, nor do

* After a long interval, these experiments were reopened by the Admiralty at Eastney, in September 1881, with 9-in. and 10-in. R.M.L. guns, against decks covered with steel plates, steel-faced plates, and wrought-iron plates. The experiments are still being proceeded with, and it would therefore be useless to give any results.

† See *Report*, June 22, 1880, *Sub-Committee on Plates and Projectiles*, pp. 15, 41, 42, 98, 168, and 173, and *Plate* I.; *R. E. Professional Papers* (Occasional Series), vol. iv., p. 172.

‡ Certain of the $12\frac{1}{2}$-in. 38-ton guns have now been chambered, and with a charge of 210 lbs. of prismatic powder the service shot will have a muzzle velocity of about 1,540 feet per second, and will pierce 19 inches of wrought iron at the muzzle.

I think that, for practical purposes—whatever may be the case from a scientific point of view—much good will come of purely mathematical inquiry in this matter.* The conditions and effects are altogether too variable and uncertain for the construction of mathematical formulæ. For instance, in recent practice, under apparently similar conditions of projectiles and plates, there has been an unaccounted-for variation of effect of something like 5 per cent. plus or minus. But we have, in the course of experiment, observed certain general principles that rule the behaviour of shot and armour under varying circumstances, and thus we have been enabled to compute penetrations approximately for all shot at all velocities, or, in other words, at all ranges.†

I will not, however, go further into this matter now than to mention one or two approximate rules which may be easily borne in the memory. Thus, with the average service conditions of weight and length of battering projectiles, a shell of good quality, with a velocity between 1,050 to 1,150 f.s., will pierce solid iron equal in thickness to its own calibre; with a velocity between 1,500 and 1,650 it will pierce iron of a thickness equal to one and a half times its calibre; and with a velocity between 2,000 and 2,200 it will pierce solid iron equal in thickness to double its calibre. The latter velocities can only be obtained in the long guns of the latest type with large charges of slow burning powder.‡

I have already had occasion to mention that a target composed of three thicknesses of $6\frac{1}{2}$-in. rolled iron plates, with layers of 5 in. of teak between them, was used against the 38-ton gun.

* For early investigations see those referred to in *Notes of Lectures on Iron Fortifications*, Chatham, 1875, p. 5.; especially Sir W. Fairbairn's, in *Reports of the Special Committee on Iron*, 1862–4; Lieut. (now Capt.) English's Paper in *R. E. Professional Papers*, vol. xix., p. 55; and published Report by Capt. (now Lt.-Col.) W. H. Noble, R.A., on *The Penetration of Iron Armour Plates by Steel Shot*, 1866. See also *R. E. Professional Papers*, vol. xvi., p. 128.

† For more recent treatment of the subject by Lt.-Col. Noble, R.A., Col. Inglis, R.E., and Col. Maitland, R.A., and others, see *Memorandum on the subject of the Perforation of Solid Unbacked Wrought-Iron Plates, &c.*, printed in Experimental Branch of Department of Dir. of Art., R. Arsenal, Feb. 25, 1881. See also Capt. English's Paper 'On Impact,' in *R. E. Professional Papers*, vol. xxiii.

‡ Capt. C. Orde Browne, late R.A., has, in a lecture delivered at the R.A. Institution since my lecture, and subsequently at the Royal United Service Institution (*see* vol. xxvi., No. cxiv,), reduced my rough rule into the formula, 'One calibre thickness of armour for every thousand feet velocity.' If the proportion $\frac{w}{d^3}$ were universal for all battering projectiles, this rule might hold good exactly; but as this is not the case, some latitude, as in my rule, appears necessary. However, Capt. Orde Browne's expression is easily remembered, and it certainly is not far from being true in ordinary practice.

This gun just perforated this target when firing its service Palliser shot with 130 lbs. of P^2 powder, at 70 yds. range, striking velocity of shot 1,420 f.s., ft. tons = 11,400; but when a fourth $6\frac{1}{2}$-in. plate was added to the target, it was a good deal more than a match for the same gun after it had been chambered, when it fired 200 lbs. P^2 powder, striking velocity of shot 1,525 f.s., ft. tons = 13,000.*

A solid $16\frac{1}{2}$-in. iron plate resisted the 38-ton gun nearly as well as the three $6\frac{1}{2}$-in. plates did, and it was also nearly pierced by a shot from the long 8-in. gun (Armstrong) already spoken of, firing an exceptional charge of 111 lbs. P. powder, at short range.†

A Palliser shot, fired from this (38-ton) gun with 130 lbs. P. powder, went through a wall composed of 5 ft. 6 in. of granite and 6 ft. of brickwork, but the wall had been shaken by previous practice.‡

At Gâvre, in 1876, a Whitworth 35-ton gun of 12-in. (maximum) calibre, fired with 120 lbs. P. powder, is reported to have sent a flat-headed steel shell of 808 lbs. through two 8-in. plates; but our experience with flat-heads would not lead us to expect so much effect upon a well-constructed two-plate target of this thickness.

I may say at once, that neither with direct nor oblique fire have flat-headed shot proved themselves, in our trials, at all equal to pointed shot in piercing armour.§

In 1877, a target composed of four 8-in. rolled iron plates, with layers of 5 in. of teak between them, was set up, at Shoeburyness, for the trial of the 80-ton gun of the pattern made for H.M.S. 'Inflexible,' and for the turret on Dover Pier. Two rounds were fired—one before, and one after the gun had been chambered. The Palliser projectiles weighed 1,700 lbs. The range was 120 yds. In the one case the shot was fired with 370 lbs. P^2 powder, and struck with a velocity of 1,495 f.s., and total energy of 26,400 ft. tons; in the other, 425 lbs. P^2 powder gave a striking velocity of 1,585 f.s., and an energy of nearly 30,000 ft. tons.||

In neither case was the target perforated, though, as the shot had got their noses an inch or two into the back plate, it was a good deal cracked and bulged behind. Had the plates been 7 in., instead of 8 in., thick, probably the last shot, at any rate, would have got through.

* *R. E. Professional Papers* (Occasional Series), vol. i., pp. 4 and 73.

† *Ibid.*, vol. i., p. 222, and vol. iv., p. 172; and *Report of Sub-Committee on Plates and Projectiles*, June 22, 1880, pp. 93 and 161.

‡ *R. E. Professional Papers* (Occasional Series), vol. i., p. 72.

§ *Report of Sub-Committee on Plates and Projectiles*, June 22, 1880, pp. 9–12.

|| *R. E. Professional Papers* (Occasional Series), vol. i., pp. 1, 6, and 77

I abstain from noticing, in much detail, the trial of an armoured target at Meppen, last year, for the same reason that I have excluded many of our own experiments—namely, because the results were, from various causes, of an inconclusive character.*

The target in this trial consisted of two wrought-iron plates, thus—

Front plate, 12 in. thick, 16 ft. 4 in. long, 3 ft. 6 in. wide,
Rear ,, 8 in. ,, 18 ft. long, 5 ft. 4 in. ,,

with an interval of 3 in. between them, lightly filled with wood (fir, I believe).

The gun was Krupp's long 24^{cm} gun; the projectiles were of steel; the charges and velocities were as follow:

Projectile. lbs.	Powder, Prismatic (1 hole). lbs.	Velocity, striking. f.s.	Striking energy. f.t.
348·3	165·3	1,876	8,508
346·5	,,	1,852	8,244

The front plate proved to be very brittle, and the rear plate was much underwelded.

In each case the shot went clean through and some 2,000 or 3,000 yds. beyond the target.

This easy victory by the shot may be accounted for, partly by the inferior quality of the plates, and partly by the bad arrangement of the target, which was not bolted together, I believe, and which certainly had too small an interval between the plates.

The gun used in this trial is only equal to perforating an 18-in. solid wrought-iron plate at its muzzle, and therefore should be only just capable of getting its shot through a well-constructed target of two plates making up together 20 in.

It will be observed that I have hitherto been dealing mainly with experiments on wrought-iron armour. I wish now to say a few words on other kinds of armour.

And first, with regard to cast-iron:

Chilled Cast-iron Armour.

As early as 1867, we tried, at Shoeburyness, some iron blocks cast in chill. In these the extreme hardness of the chilled surface was well illustrated, but the brittleness was so marked that we hesitated to go further with this kind of protection.†

But it was taken up in Prussia, and in 1869 a chilled cast-iron

* *R. E. Professional Papers* (Occasional Series), vol. iv., p. 181.

‡ *Ibid.* (Second Series), vol. xvii., p. 206.

casemate front, egg-shaped (thickness of metal about the port, 27 in.), underwent a considerable trial, at Tegel, with 72-prs. and 96-prs., and it stood fairly well. The indents were very slight, but the material, as usual, was extremely brittle, and to adopt the expressive language of a report quoted in the 'Professional Papers of the Corps of Engineers, U.S. Army,' it was 'pretty well cracked up.'

The next trial of chilled cast-iron armour was at Magdeburg, in 1874, against a very massive rounded target made by Grüson, and, although both from the form of the structure and the hardness of the material, individual shot were very effectually turned off it, yet repeated blows caused serious injury.

Still, the Germans and Belgians have adopted this mode of construction for both shields and turrets—especially for a number of 21^{cm} and 28^{cm} breech-loading muzzle-pivoting guns for the defence of the mouths of rivers. Some of the other European powers also are using it, to a greater or less extent, for both inland and coast fortresses.

The chief advantage of this material is that it can be made of any shape, and therefore rounded and sloping surfaces can be presented to the shot; and it affords also a certain facility for varying at will the thickness of the metal in the different parts of a wall.

The problem is whether for a given sum of money greater efficiency and more complete protection can be obtained by means of cast iron than with wrought iron, and nothing but a fair trial between two structures under heavy fire can, in my opinion, solve this.

I must not omit altogether to mention that a chilled cast-iron block was used last year in the Meppen trials, but I am afraid it did not afford much reliable information.

It must be borne in mind that the guns protected by cast-iron walls must be muzzle-pivoted, and also, almost of necessity, breech-loaded.*

Steel and Compound Armour again tried.

Next, as to experiments with steel, and compound steel and iron, armour.

Even as early as in 1859 armour plates of mild steel and steely iron, and iron and steel combined, and various kinds of steel plates tempered in oil and water had been tried, and all failed in a greater or less degree when they came to stand the test of shot blows.

I have already said that when the employment of steel for armour

* Herr Grüsen has published very full plates and photographs of his various constructions in chilled cast iron, which are worthy of examination.

was taken up again in this country in 1867, the steel was beaten by simple wrought-iron plates.

And so the matter of steel armour rested until the Italians, in 1876, boldly reopened the question by setting up two armour plates (made by M. Schneider, of Creusot) of soft forged steel $21\frac{3}{4}$ in. thick, for trial at Spezia. The plates were about 11 ft. long and 4 ft. 7 in. wide, and they were backed with massive oak, covering a strong iron skin well supported in rear.*

For comparison with these, three iron plates of nearly the same dimensions as the steel plates, and similarly supported, were tried at the same time, as well as two plate-upon-plate targets, each consisting of iron plates 11·8 in. and 9·8 in. thick, with 12 in. of wood between them, and backing of timber and iron behind them. I must also mention two targets composed of 8-in. wrought-iron plates backed by blocks of chilled cast iron of 'Gregorini' metal, 14 in. thick. In one of these the chilled blocks touched the front armour, in the other 12 in. of wood were interposed.

In all the targets there was the same total thickness of 4 ft. 4 in., made up of about 22 in. of armour and 30 in. of timber and skin.

The general result of the trial was this:

One steel plate was a good deal cracked, and had its end knocked away by two blows from a 10-in. and one from an 11-in. gun throwing chilled cast-iron projectiles, and the fourth round from the 100-ton gun with a 2,000-lb. chilled cast-iron projectile striking with a velocity of 1,500 f.s., and a muzzle energy of 31,000 ft. tons, dashed the plate to pieces, though it apparently could not quite perforate it. The other thick steel plate was completely demolished by a single round from the same 100-ton gun.

The thick wrought-iron plate made in England was much less injured generally by the lighter guns than was the steel plate, though the indents in it were deeper, but the 100-ton gun sent its shot through all the iron plates, and also broke them in two.

The 'plate-upon-plate' targets did not do so well as the solid plates, and the targets with the chilled iron backings entirely succumbed to a single blow on each from the 100-ton gun.

The results of the trial were seriously invalidated by the narrowness of the plates used; a width of 4 ft. 7 in. being altogether too little for a plate which is to receive a 17-in. shot, and, on this account, these

* *R. E. Professional Papers* (Occasional Series), vol. i., p. 79, and vol. ii., p. 1; Report of Col. (now Lieut.-Gen., retired) Younghusband, R.A., F.R.S., Supt. of Royal Gun Factories, on visit to Spezia, in October, 1876.

costly and elaborate trials at Spezia have afforded much less useful information than they ought to have given.

The brittleness of the steel, and its consequent incapacity for resistance to repeated blows, is a striking feature of these trials; the failure of the plate-upon-plate targets, through their being a bad imitation of our construction, is another; the utter collapse of the target with the chilled iron blocks is a third; and the defective plan of holding armour by simply screwing bolts into the backs of plates is a fourth.

It is to be regretted, also, that these trials did not give us a more exact measure of the armour-piercing power of the 100-ton gun, which was a counterpart of the four which we are to mount at Gibraltar and Malta.

In 1879 the Italians again experimented at Spezia upon thick steel plates.*

This time the plates were nearly 28 in. thick, and were entirely cased in 1-in. plate boxes, which dispensed with bolting. They were narrow plates, as before (4 ft. 7 in. wide and 9 ft. long), weight about 20 tons each; but these plates were so utterly destroyed by a single round each, from chilled iron or steel projectiles from the 100-ton gun firing 550 lbs. of Fossano powder, that the trials had to be discontinued without telling much more than was known before. The forged steel projectile made by Whitworth seems to have penetrated the deepest (21·65 in.), and remained entire, but it was somewhat set up.

It is understood that the Italians will continue these trials of armour plates shortly.†

With the earlier collapse of simple steel armour before us, our English manufacturers were set to work, in 1877, to see if they could not produce something which, while it should have the resisting qualities of steel, should be free from the serious defect of breaking up under almost a single heavy blow. In the course of that year and the following, therefore, we tried every possible kind of armour that could be produced in Sheffield for this purpose. I think more than fifty methods were subjected to trial.‡

* *R. E. Professional Papers* (Occasional Series), vol. iv p. 179.

† I have no reports of any subsequent trials in Italy, but I believe the Italian Government propose, in the course of the present year (1882), to compare the resistance of thick (48 cm.) compound armour plates of English manufacture with steel plates made by M. Schneider, of Creusot, using the 17·72-in. gun of 100 tons and chilled cast-iron projectiles.

‡ *R. E. Professional Papers* (Occasional Series), vol. i., pp. 228–33; *Report of Sub-Committee on Plates and Projectiles*, June 22, 1880, particularly pp. 11–17 and tables in Appendix 3; *Proceedings of R. A. Institution*, Sept. 1881, vol. xi., No. 7, p. 477; *Notes, &c.*, by Capt. J. P. Cundill, R.A.

Some were utter failures, some promised well at one time and failed at another, but the result of the whole has been that compound plates, in which a steel face (about one-third the thickness of the entire plate) has been perfectly welded to a wrought-iron back, without injuring the two materials, have met with most success.

The object of this kind of armour is, that while the face shall be sufficiently hard to break up, or to take a great deal of work out of, the shot, the soft wrought-iron back shall hold the mass together, in spite of the cracking of the steel face.

One of the principal points, of course, has been to determine the best degree of hardness, or, in other words, the best proportion of carbon that should be given to the steel for these purposes.

As this matter is still under consideration, I cannot say more about it on the present occasion than that the manufacture of these compound plates can scarcely yet be said to be uniformly successful, but that when they are good they seem to offer, for a few moderately severe rounds at least, resistance compared with that of plain wrought-iron plates as 4 to 3; that is to say, a 9-in. compound plate will be about equal to a 12-in. iron plate, and, with oblique fire, they certainly are very successful in turning and breaking up shot of all kinds of form and material.*

The trials have been made principally with 7-in. and 9-in. guns, with both direct and oblique fire, and with all kinds and forms of projectiles, and these are shortly to be continued for the Admiralty at Shoeburyness, with much greater thicknesses of armour, for which the 38-ton gun is to be used.†

Within the last few days the French have carried on important trials at Gâvre, when some steel plates, averaging 18 in. in thickness,

* *R. E. Professional Papers* (Occasional Series), vol. ii., pp. 185–96, and vol. iv., pp. 173–8.

† *Ibid.*, vol. iv., pp. 191–3; *Final Report of Sub-Committee on Plates and Projectiles*, March 31, 1881, pp. 5–7, and Appendix, pp. 10–12. Among recent successes with compound armour plates may be mentioned that attending the trial of an 11-in. plate, 10 ft. by 5 ft. 6 in., weight 10 tons 16 cwt. 20 lbs., made by Messrs. J. Brown & Co., of Sheffield, and tried at Shoeburyness late in 1881. This plate was backed by 2 ft. of English oak, and received 4 rounds from the 9-in. M.L. gun of 12 tons, of which one was with a cast-steel shell, and two from the 12·5-in. M.L. 38-ton gun, both of which were of steel. Though not capable of resisting the 12·5-in. projectiles, it stood, on the whole, remarkably well, especially where the four 9-in. shells struck within a small compass. Some remarkable effects were exhibited on this plate after the trial, due to the steel face having broken in coned fractures at each shot mark from the 9-in. gun, as is not unusual; but in this case a large surface of the plate was brought away, leaving a succession of conical mounds of steel standing out, each with a dent formed by the point of the shot on its summit.

produced by foreign makers, and a foreign-made wrought-iron plate with a hard face, and a compound plate made by Messrs. Cammell, of Sheffield, were fired at by a 32^{cm} steel B.L. gun with 760-lb. projectiles and 210 lbs. charge of powder, and so far as my information goes, the English compound plate behaved the best of all. The steel plates broke up very freely, as usual.

Until further experience has been gained with heavy blows from large projectiles of hard material, it would not be wise to speak confidently as to the ultimate success of this kind of armour.*

In the meantime the Admiralty have adopted 9-in. compound plates for the turrets of H.M.S. 'Inflexible.' The French, I hear, are seriously taking it up for their ships, but we have not yet decided to use any of this kind of armour in land works.

The use of these compound plates will involve a new mode of fastening them, because bolt-holes passing through the steel would be inadmissible; but we hope we have got over all difficulty in this respect by screwing into the wrought-iron back a seat for a spherical nut to hold the armour bolt without confining it laterally.†

A plate, on a novel principle, made by Sir J. Whitworth, deserves notice, notwithstanding that it did not succeed very well. It was composed of a mass of fluid-compressed steel, pierced all over, at regular intervals, by screwed plugs of an extremely hard steel, so arranged that, wherever a shot might strike, it would have to cut into one of the hard plugs.‡

Behaviour of Battering Projectiles of various kinds.

Perhaps I shall now be expected to say a few words as to the effect of the different kinds of armour upon battering projectiles of various makes and forms.

* A series of experiments with the 12-in. B.L. gun of 43 tons against 18-in. steel-faced plates is arranged to come off at Shoeburyness in the course of the present year (1882). The primary object of the trials is to guide the manufacture of hard-steel projectiles for the attack of steel plates, but no doubt valuable information will be gained in the matter of the resistance of compound armour under heavy blows delivered at high velocities.

† This system gave admirable results in the case of No. 43 target, experimented upon by Sub-Committee on Plates and Projectiles. See *Report*, June 22, 1880. The target consisted of a 10-in. compound plate, 8 ft. long and 6 ft. wide, held by six 3-in. bolts to timber supports. The plate received six oblique rounds from the 9-in. 12-ton gun, and was at last completely broken up; but not one of the armour bolts was broken, though they were bent in some instances almost at right angles. For a somewhat fuller description of this method of bolting, see *R. E. Professional Papers* (Occasional Series), vol. iv., p. 178.

‡ *R. E. Professional Papers* (Occasional Series), vol. ii., p. 187.

First, then, it may be said that although chilled cast-iron shell nearly always break up on striking wrought-iron armour directly at high velocities, yet in doing so they seem to lose very little of their useful energy, and in both direct and oblique fire against this armour chilled cast-iron shells hold their own fairly well against other kinds of projectile.

The only instance in which I have seen any kind of projectile strike thick iron armour obliquely (angle from normal 30°) at a velocity of over 1,500 ft. per second, and remain entire, was that of a 9-in. forged steel shell made by Whitworth.*

The following are the most noticeable instances of chilled cast-iron projectiles remaining entire after doing good work upon wrought-iron armour hitting directly:

Round.	Calibre.	Weight. lbs. ozs.	Plate.	Striking velocity.
2,332	3 in.	10 4	$4\frac{1}{2}$ in.	1,699 f.s.
2,165	6 „	80 0	5 „	1,026 „
2,249	8 „	182 8	8 „	1,108 „
2,260	8 „	182 8	10 „	1,337 „

Both forged and cast-steel shell, well tempered, have been passed through great thicknesses of wrought iron in direct hitting without being injured (Rds. 2,192, 2,195); the same 9-in. forged shell of Whitworth fluid-pressed steel has been passed three times through 12-in. wrought-iron armour plates without breaking up (Rds. 2,126, 2,140, 2,169); and a forged steel shell, hardened in oil, from the 8-in. long gun (Rd. 2,284), remained entire and very slightly altered in form in a $16\frac{1}{2}$-in. iron plate, which it struck with a velocity of over 2,200 ft. per second.†

The chief advantage to be gained by the use of these very costly steel projectiles over the simple chilled cast-iron projectiles appears to lie in the possibility of their being used for carrying a bursting charge of gun-cotton, or some such violent explosive, through thick iron armour before explosion. This the ordinary chilled iron shell can never do.

As to the effect of chilled cast-iron armour upon projectiles, there is not sufficient known at present to admit of much being said about it.

On steel-faced armour the best effect has been obtained with cast-

* *Report of Sub-Committee on Plates and Projectiles*, June 22, 1882, Table 16, p. 74, round 2,213. In another round (2,292) in the same table a similar shell was cracked only.

† All these rounds are described in *Report of Sub-Committee on Plates and Projectiles*, June 22, 1882.

steel shell in direct fire, and perhaps rather the best effect with forged steel shell in oblique hitting, but in this latter mode of attack on steel, all steel projectiles that have been yet tried have gone to pieces.

Steel-faced armour completely baffles chilled cast-iron projectiles.

For direct fire, the longer the head of the projectile the greater will be the effect on iron armour, but in oblique fire the best effect has been produced with heads struck to a radius of two diameters of the shot's body. As I have already said, flat heads are much inferior to pointed heads in both direct and oblique fire.*

II.—ACCOUNT OF THE MATERIALS USED FOR ARMOUR AND THEIR MANUFACTURE.

Manufacture of Wrought-Iron Armour Plates.

Beginning with wrought-iron armour:—For this, as made at Sheffield, the best cold-blast pig with a proportion of Cumberland hæmatite is generally used. Roughly speaking, it takes $2\frac{1}{2}$ tons of pig, or 2 tons of ball furnaced iron—that is, of puddle ball—to make 1 ton of finished armour plate, and in the last heating of all, when the iron is in a very costly state, there is a loss by the actual burning away of the iron of abut 10 per cent. It takes also about $6\frac{1}{2}$ tons of coal to make a ton of armour.

Perhaps the shortest way of giving an account of the manufacture of rolled iron armour will be to say how some one plate in particular has been made, and I will select for this purpose one of the heaviest ever produced.

This was one of the 8-in. plates made for the target to test the 80-ton gun at Shoeburyness. Its finished dimensions were—length 16 ft., width 10 ft., and its weight 23 tons.

For its manufacture, 1,170 slabs 30 in. long, 12 in. wide, and 1 in. thick, were made from the puddled ball and bar. These were piled, furnaced, and rolled into 65 plates about 5 ft. square and from 1 in. to $1\frac{1}{2}$ in. thick, called small moulds. These, again, were piled and rolled into quarter-moulds, and the quarter-moulds into armour-plate moulds, and the pile for the last rolling was made up of three moulds about 10 ft. square, two of 7-in. and one of 3-in. thickness. As they entered the furnace for the last heating they weighed about 35 tons; as they came out after about 12 hours they weighed $31\frac{1}{2}$ tons.

They were rolled down in the last rolling from 17 in. to 8 in.; so

* *Report of Sub-Committee on Plates and Projectiles*, June 22, 1880, p. 12.

that, in a certain sense, this plate may be said to have been made by rolling a column of iron nearly 100 ft. high down to one only 8 in. high. The fibrous character of a plate depends largely upon the amount of reduction in the last rolling.

The rolls are plain cast cylinders; those used in the present case are about 3 ft. in diameter, 12 ft. long, and each one of the pair weighs nearly 20 tons. They are driven by very powerful steam machinery, and made to reverse their running, so that the plates are sent through one way and then back again, and so on, the rolls being brought nearer together each time, until the plate is brought down to the required thickness.

The specific gravity of a good iron armour plate is about 7·625.

Armour plate iron is not made for high tensile strength, but it is essential that it should draw out well, and reduce in cross section some 20 or 30 per cent. before breaking.

It has been our practice to prove a very large proportion of the plates made for iron fortifications by shot capable of nearly perforating them. Pieces of those which could not be thus proved have been broken under hydraulic presses, and otherwise treated.

Armour bolt-iron is similar to armour plate-iron, but we require a reduction of area of fracture of at least 40 per cent. when broken by a falling weight test, and we generally get a larger reduction than this.

As forged (hammered) iron armour plates are obsolete, I need not describe their manufacture.

Manufacture of Chilled Cast-Iron Armour.

As regards chilled cast iron there is not much to be said, further than that Herr Grüson, of Magdeburg, the principal manufacturer of it, runs his blocks, for fortifications, direct from cupolas into sand moulds, chilling the faces which are to form the fronts of the blocks against masses of cast iron. Some of the chills are twice the weight of the casting itself; the chilling action generally extends two or three inches into the metal. Single blocks have been used as heavy as 50 tons. The cost of these blocks may be taken as rather more than half the cost of wrought-iron armour plates per ton, but then the cast iron has to be used in masses more than twice the thickness of the wrought iron which would give the same protection.

Manufacture of Compound Plates.

With regard to compound plates there is more to be said, but I must condense it into a few words.

All the most successful compound plates have been made of ordinary armour plate iron faced with Bessemer steel. Of course an equally good, or even better, face might be given by using crucible steel, but the cost and difficulty attending the use of this kind of steel would be enormous. In fact, I think it may be said that but for the Bessemer and Martin-Siemens processes it would have been practically out of the question to make compound plates at all.

The most simple and effective process of manufacture of these plates is as follows:

First, a rolled iron armour plate of the usual quality is made, and on it is laid round its edges a wrought-iron frame, the thickness of the armour plate and the depth of the frame depending upon the thickness required in the finished plate.

The plate and frame are then placed in an ordinary plate-heating furnace, and when at a welding heat they are brought out, and molten steel made by the Bessemer process is poured out of large ladles on to the surface of the plate up to the brim of the frame. The mass is then allowed to cool, and is afterwards re-heated and rolled down into an armour plate of the desired thickness. The edge of wrought iron is afterwards planed off.*

Instead of having a simple frame round the edges of the plate it has been proposed to subdivide the surface into squares, as those of a chess board, in order that, by breaking the continuity of the steel, the cracks caused by shot blows may be stopped short, and with the same object an officer of Royal Artillery has proposed to subdivide the steel by firm cuts across its face; but we have not yet seen the effect of these expedients in actual trial.†

The successful union of the steel and iron masses in these plates is very marked. A complete fusion seems to take place, and the natures of the two metals so far intermingle that it is sometimes hard to fix upon an exact line where the steel ends and the iron begins.

The degree of hardness most suitable for the steel in these plates is supposed to be obtained with about 0·6 per cent. of carbon.‡

* Since this account was written the process of making these compound plates at Sheffield has been somewhat changed. The wrought-iron armour plate is now placed vertically in a mould to receive the steel from either a Siemens furnace or from a Bessemer ladle. One of the firms does away with the wrought-iron frame round the wrought-iron plate, by using a cast-iron mould of the proper size for the required plate. The other uses a hard steel face plate, between which and the wrought-iron back the molten steel is poured. They have no difficulty now in making these compound plates 18 in. in thickness and 30 tons in weight, but they are very expensive.

† I have not heard that these proposals have ever been practically dealt with.

‡ As much as 0·76 per cent. of carbon has been used in the steel of recent compound plates, which have given good results.

It is thought that the thickness of steel in a compound plate should be between $\frac{1}{4}$th and $\frac{1}{3}$rd of its entire thickness.

III.—DESCRIPTION OF THE PRINCIPAL ARMOURED DEFENCES SET UP.

I now come to the third and last part of the subject, which comprises a brief description of the principal armoured works erected by us.

The following tables give the number and nature of the guns for which protection has been provided, up to the present time, in each fort or battery at home and abroad, as well as a short description of the iron protection itself.

From these it will be seen that at home 434 guns, ranging between the 7-ton and 80-ton, have been provided for, and abroad 91 guns between the 12-ton and 38-ton, making altogether a total of 525 battering guns behind armoured walls.

Nature of Iron Protection	No. of Guns	Description of Guns
Home Stations:		
Shields in masonry work.........	7	7-in., 7 tons.
	110	9 ,, 12 ,,
	113	10 ,, 18 ,,
	42	11 ,, 25 ,,
	29	12½,, 38 ,,
Do., do., with guns on turntables	2	10 ,, 18 ,,
Iron batteries	54	10 ,, 18 ,,
	85	12½,, 38 ,,
Turret	2	16 ,, 80 ,,
Total...............	444	
Foreign Stations:		
Shields in masonry work.........	28	9 ,, 12 ,,
	39	10 ,, 18 ,,
	2	11 ,, 25 ,,
	9	12½,, 38 ,,
Do., do., with guns on turntables	6	12½,, 38 ,,
Iron batteries	5	19 ,, 18 ,,
	2	12½,, 28 ,,
Total	91	
General total	535 guns	

Home Stations.

Name of Station and Battery		Nature of Iron Protection	Description of Guns					
			7 in. 7 tn.	9 in. 12 tn.	10 in. 18 tn.	11 in. 25 tn.	12½ in. 38 tn.	16 in. 80 tn.
Portsmouth	Gilkicker Battery	Shields. Three 5-in. plates, or two 8-in. plates, and frame 1′ 7½″ deep	..	..	10			
	Horse Sand Fort and	Iron front. Two 5-in. and one 7-in. plate at ports, three 5-in. plates elsewhere, backing bars 12″ deep, and piers	..	..	25	..	24	
	No Man's Land Fort		..	..	25	..	24	
	Spit Bank Fort	Iron front. Three 5-in. plates; prepared for fourth plate	..	..	..	..	9	
	St. Helen's Fort	Curved front. Three 5-in. plates, and frame 1′ 4″ deep. Guns on turntables	..	..	2			
	Do. do.	Straight front. Three 8-in. plates	..	..	..	..	1	
	Hurst Castle	Shields. Three 5-in. plates, and frames 1′ 7½″ and 2′ 1″ deep	..	5	23	..	10	
Isle of Wight, Sandown Fort		Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	4	8			
Portland	Portland Breakwater Fort	Iron front. Three 6½-in. plates	..	..	..	..	14	
	Nothe Fort	Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	4	6			
Plymouth	Bovisand Battery	Do. do. do.	..	9	14			
	Plymouth Breakwater Fort	Iron front. Outer thickness 5-in. plates, second and third do., 5-in. bars, backing bars 12″ deep; extra 5-in. plate at ports	..	..	4	..	14	
	Picklecombe Battery	Double tier shields. No. 15 with three 5-in. plates, and No. 4 with two 5-in. plates; prepared for third plate	4	19	19			
	Drake's Island Batt.	Shields. No. 2 with three 5-in. plates, and No. 7 with two 8-in. plates; frames 1′ 7½″ deep	..	9				
Pembroke	Stack Rock Fort	Shields. Three 5-in. plates, and frames 1′ 7½″ deep	..	..	16			
Dover.	Admiralty Pier	Turret. Three 7-in. and two 2-in. plates	..	..	..	..	..	2
Mersey.	Seaforth Battery	Straight front. Two 8-in. plates; provided for third plate	..	..	..	..	4	
Thames	Coalhouse Fort	Shields. No. 13 with three 5-in. plates, and No. 4 with two 5-in. plates; provided for third plate. Frames 2′ 1″ deep	..	..	..	13	4	
	Cliffe Fort	Shields. No. 6 with three 5-in. plates, and No. 2 with two 5-in. plates; provided for third plate. Frames 2′ 1″ deep	..	..	..	6	2	
	Shornmead Fort	Shields. Two 5-in. plates; provided for third plate	..	..	..	11		
	Tilbury Fort	Shields. Two 5-in. plates; provided for third plate; 1′ 7½″ and 2′ 1″ deep	..	7	..	1		
	New Tavern Fort	Do. do. do.	..	6	..	1		
Medway and Sheerness	Garrison Point Fort	Double tier shields. No. 3 with three 10-in. plates on lower tier, and two 9-in. plates on upper tier; No. 34 with three 5-in. plates, and No. 4 with two 5-in. plates; provided for third plate	..	28	10	3	3	
	Hoo Fort	Shields. No. 4 with two 8-in. plates, and No. 7 with one 8-in. plate; provided for third plate	..	11				
	Darnet Fort	Shields. No. 6 with two 8-in. plates, and No. 5 with one 8-in. plate; provided for second plate.	3	8				
Harwich.	Landguard Fort	Shields. Three 5-in. plates, and frames 1′ 7½″ and 2′ 1″ deep	..	..	5	..	5	
Cork	Carlisle Fort	Shields. No. 3 with two 8-in. plates, and No. 2 with three 5-in. plates, frames 1′ 7½″ deep	..	..	2	3		
	Camden Fort	Shields. Two 8-in. plates, and frames 1′ 7½″ deep	..	..	..	4		

Foreign Stations.

Name of Station and Battery			Nature of Iron Protection	Description of Guns				
				7 in. 7 tn.	9 in. 12 tn.	10 in. 18 tn.	11 in. 25 in.	12½ in. 38 tn.
Malta		Abercrombie's Bastion	Shields. Three 5-in. plates, and frames 1′ 7½″ deep	..	..	2		
Malta		Do. do.	Shields. One 4-in., one 5½-in., one 5-in., and one 1½-in. plates	..	2			
Malta	St. Elmo	Ball's Curtain	Shield. One 4-in., one 5½-in., one 5-in., and one 1½-in. plates	..	1			
Malta	St. Elmo	Do. Bastion	Shields. Three 5-in. plates, and frames 1′ 7½″ deep	..	..	3		
Malta	St. Elmo	St. Gregory's Bn.	Shield. Three 5-in. plates, and frames 2′ 1″ deep	..	..	..	..	1
Malta	Valetta	St. Lazarus Bast.	Do. do. do.	..	..	..	..	1
Malta	Valetta	St. Sebastian do.	Shield. One 5½-in., one 5-in., one 1½-in. plates	..	1			
Malta	Valetta	English Curtain	Do. do. do.	..	1			
Malta	Ft. Tigné	S.E. Face	Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	2			
Malta	Ft. Tigné	N.E. Front	Shields. One 4-in., one 5½-in., one 5-in., and one 1½-in. plates	..	2			
Malta	Ft. Tigné	N.E. Face	Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	2			
Malta		St. Angelo. No. 2 Batt.	Shields. One 5½-in., one 5-in., and one 1½-in. plates	..	3			
Malta	Ricasoli	No. 1 Bastion	Shield. Three 5-in. plates, and frame 2′ 1″ deep	..	..	..	..	1
Malta	Ricasoli	No. 2 do.	Do., do., do., 1′ 7½″ deep	..	..	2		
Malta	Ricasoli	No. 3 do.	Shields. One 4-in., one 5½-in., one 5-in., and one 1½-in. plates	..	..	2		
Malta	Ricasoli	No. 5 RD Curtn.	Shields. Three 5-in. plates, and frame 2′ 1″ deep	..	..	..	2	
Malta	Sliema Point	Sliema Pnt. Bat.	Curved front. Three 5-in. plates, and frame 1′ 4″ deep. Guns on turntables	..	..	..	..	2
Malta	Sliema Point	Do.	Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	..	2		
Malta		St. Lucien Fort	Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	..	3		
Malta		Delimara Fort	Shields. Two 9-in. plates, and frame 1′ 10″ deep; prepared for third plate	..	..	..	..	6
Gibraltar		Montague Bastion	Shields. One 4-in., one 5½-in., one 5-in., and one 1½-in. plates	..	..	3		
Gibraltar		Orange do.	Do. do. do.	..	..	2		
Gibraltar		King's do.	Do. do. do.	..	..	4		
Gibraltar		South do.	Do. do. do.	..	..	3		
Gibraltar		Victoria do.	Do. do. do.	..	..	2		
Gibraltar		New Mole do.	Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	4			
Gibraltar		Alexandra Battery	Curved front. Three 6-in. plates, and frame 1′ 10″ deep. Guns on turntables	..	..	..	..	1
Gibraltar		King's Bastion	Do. do. do.	..	..	..	..	1
Gibraltar		Wellington Front	Curved front. Two 9-in. plates; prepared for third plate; frame 1′ 10″ deep. Guns on turntables	..	..	..	..	1
Gibraltar		Prince Albert Battery	Do. do. do.	..	..	..	..	1
Gibraltar		Engineer Battery	Shield. One 4-in., one 5½-in., one 5-in., and one 1½-in. plates	..	..	1		
Gibraltar		9th Rosia do.	Do. do. do.	..	..	3		
Halifax		Fort Charlotte	Shields. Three 5-in. plates, and frame 1′ 7½″ deep	..	..	4		
Halifax		Ives Point	Do. do. do.	..	6	3		
Bermuda		Fort Cunningham	Iron front. Outer thickness 5-in. plate, second 5-in. bars, third 5-in. plate, with backing of bars 12″ deep, extra 5-in. plate at ports	..	..	5	..	2
Bermuda		Alexandra Battery	Shields. One 5½-in., one 5-in., and one 1½-in. plate	..	4			

Note.—There are, in addition to the above, 11 casemates for 9-in. 12-ton guns at Fort Clarence, Halifax, which are fitted with railway bar embrasures of a special pattern.

Casemate Shields described.

With regard to casemate shields in masonry works, *Plates* III. and IV. represent one of these, 9 ft. high, which is suitable for a 25-ton or 38-ton gun.

A smaller kind, 8 ft. high, has been used for guns below the 25-ton gun.

This type of shield consists broadly of the supporting structure, which we call the shield frame, and the armour.

The first point is to secure the frame to the masonry, so that it cannot be driven back. This is done either by extending the base and top plates into the masonry, or by the use of massive dove-tail pieces, under the frame, provided with stops. The base plates are also bolted down to the masonry.

These shield frames are made of $\frac{3}{4}$-in. plate, and 6-in. by 6-in. angle-irons, and weigh from $8\frac{1}{2}$ to 10 tons each when empty. They are filled with concrete when erected.

The armour generally consists of three thicknesses of 5-in. armour, with intervals of 5 in., filled with brickwork or concrete between them, and round the opening of the port there are strong wrought-iron frames to keep this filling in place. Between the inner plate and the shield frame there is an inch interval, usually filled with wood. Each thickness of armour is bolted to the one next behind it, and the rear plate to the shield frame. No armour bolts show in the casemate.

The weight of three thicknesses of 5-in. armour is about 25 tons, and the weight of one of the smaller of these shields complete is about 56 tons.

Some Shields have Thicker Armour.

Some of these shields are protected by two thicknesses of 8 in. plate, and some by three; in one instance—namely, in the shields for 38-ton guns, at Garrison Point Battery, Sheerness—there are three thicknesses of 10-in. plates.*

Open Battery Shields.

Seaforth and St. Helen's Casemate Shields.

There is a modification of this type of shield suited to open batteries to which over-head cover can be added at pleasure; and in more recent casemated works for 38-ton guns, as at Seaforth Battery,

* For more full description of casemate shields, see *Notes of Lectures on Iron Fortifications*, Chatham, 1875, pp. 14–16.

Liverpool, and St. Helen's Fort, off the Isle of Wight, there is another, perhaps the best arrangement of all, in which the armoured protection occupies a frontage of 20 ft. between the masonry piers (*Plates* IVA IVB.).

Hoo and Darnet Shields.

Two-tier Shields.

The shields at Hoo and Darnet Forts, on the Medway, are of a somewhat different pattern, and the two-tier shields in Garrison Point Battery, Sheerness, and Picklecombe Battery, Plymouth Sound, are of another kind, shown in *Plate* V.*

Range of Fire in Shield Ports generally.

In these shields the ports are generally cut for a lateral training of 60°, elevations up to about 10°, and depressions down to 4°, according to the circumstances of the works.

Casemates for Heavy Guns on Turntables.

The next kind of protection to be noticed is that given to heavy guns mounted on turntables. These occur in certain positions where an extended lateral fire of about 120° is required—as at

Spithead defences,	St. Helen's Fort...........	two	turntables	for	18-ton	guns.
Gibraltar ,,	Prince Albert's Bastion King's Bastion......... Wellington Front ... Alexandra Battery ...	four	,,	,,	38-ton	,,
Malta ,,	Sliema Battery.........	two	,,	,,	,,	,,

The general arrangement of the front part of one of these casemates is shown in *Plate* No. VI., from which it will be seen that there are two gun ports in each, and the gun being mounted on the ordinary casemate carriage and platform, fires through 60° out of each port, the turntable being used merely for transferring the gun from one port to the other.

The front protection is on much the same principle as that of the shields already described, only it is of necessity circular in plan.

The armour is usually in two thicknesses of 9-in. plate, or in three of 6-in. (at St. Helen's and Sliema Point batteries it is in three thick-

* The two-tier shields are also more fully described in *Notes of Lectures on Iron Fortifications*, Chatham, 1875, p. 17.

nesses of 5-in.). The roof structure is of strong girders, with arch plating between them, and carries some 6 ft. of concrete, and is thoroughly bomb-proof.

The turntable consists of a very stiff circular frame, varying from 20 ft. to 23 ft. in diameter, and is strong enough to bear the weight and shock of the gun when fired in any position of training.

It revolves on a set of conical rollers running in a live ring under the edge of the table, and is held in position by a central spindle which passes into a massive casting, strongly bolted down. The table is turned by hand-gear, working into cogs on its outer rim. It is locked by a set of tumbler stops when the gun is in position for firing.

The larger-sized turntable weighs about 37 tons. It can be lifted bodily, without dismounting the gun, for purposes of inspection and cleaning.

It is proposed that the guns on these turntables should be turned to the rear for loading, where there will be every facility for the operation.

Sea Forts.

I now come to the sea forts, the batteries of which, as I have said early in this Paper, are protected by walls composed continuously of iron.

These are the following:

Plymouth Breakwater Fort.

Plymouth Breakwater Fort.—This iron battery is oval in form, 144 ft. long and 114 ft. broad, and stands about 100 yds. behind the central part of the Breakwater (the floor being about 16 ft. above high water mark), on a mass of masonry resting on a rocky bed about six fathoms below low water mark. It will mount fourteen 38-ton guns, and four 18-ton guns, firing through small ports (21 ft. 9 in. from centre to centre). The ironwork was commenced in 1867, and finished in 1870.

I shall not stop to describe this work further than to say that there are four thicknesses of 5-in. armour about the port, and three thicknesses supported by massive armour bars on edge elsewhere. The piers supporting the roof structure are separate from the armoured wall. The roof is of the usual girder construction, and bomb-proof throughout.

There is to this, and to all the other sea forts, an entrance port into which, in preparing for action, a massive armoured shield on wheels is run, and over the entrance is a very strong cantilever beam for hoisting the guns and other heavy weights from vessels into the battery, and *vice versâ*, by means of heavy hoisting gear placed on the roof.

I do not give a diagram of this fort, because the general principles of our armoured structures are better illustrated in some of the other forts.*

Fort Cunningham, Bermuda.

It may be mentioned here that there is another iron battery of this type at Fort Cunningham, Bermuda, constructed about the same time as the Plymouth Fort, only it has straight instead of curved faces; it has also small ports for two 38-ton and five 18-ton guns.†

Portland Breakwater Fort.

The next kind of iron battery is that represented by Portland Breakwater Fort. (*See Plates* VII. and VIII.)

This fort occupies a site at the end of the Breakwater at Portland. Its foundations rest on a clay bottom about 10 fathoms below low water mark. The battery is circular (radius about 58 ft.), and its floor is about 23 ft. above high water mark. It is to mount fourteen 38-ton guns. The gun ports are 23 ft. 4 in. from centre to centre.

With regard first to the inner structure of the battery, this consists, generally speaking, of two strong rings of box-girder construction going all round the battery, one at the level of the floor, and the other at the level of the roof, against which the armoured wall rests. The remainder of the inner or supporting structure consists of strong iron pillars, in couples, between the ports, which carry a ring of solid armour bars round the entire battery to form the front support of a bomb-proof iron roof. The rear of the roof is supported on a ring of box-girders resting on masonry piers.

The armoured wall consists of three thicknesses of 6½-in. plates, with port frames, 2¼-in. thick, round the ports.‡

Spitbank Fort.

Spitbank Fort, which is the innermost of the Spithead Forts, is of similar construction to Portland Breakwater Fort, except as to form and size.

* *Notes of Lectures on Iron Fortifications*, Chatham, 1875, p. 18.
† *Ibid.*, p. 19. ‡ *Ibid.*, p. 19.

The iron battery mounts nine 38-ton guns, and occupies the outer or seaward side of a fort of about 150 ft. in diameter, the rest of the fort being of masonry. The battery floor is about 16 ft. above high water, and in all respects the construction of the Portland Fort applies to this, except that the armoured wall here consists of only three thicknesses of 5-in. plate, which are prepared to receive a fourth when necessary. The ironwork of this battery was completed in 1875.*

Horse Sand and No Man's Land Forts.

The next works to be described are the two great forts at Spithead, standing on either side of the main channel, about 2,000 yds. apart. (*See Plates* IX. and X.) They are named from the shoals on which they stand.

Their foundations were laid some two or three fathoms below low water, and occupy circles of about 230 ft. diameter. The masonry work is carried up to a height of about 16 ft. above high water, and at that level commences the two-tier circular iron battery for 24 guns on the lower floor, and 25 guns on the upper. As hitherto intended these were to be all 38-ton ($12\frac{1}{2}$-in.) guns below, and 18-ton (10-in.) guns above, but it is more than probable that in each tier some of these will be superseded by the new type of long, more powerful, and more suitable breech-loading guns.

The two forts are almost identically the same in dimensions and construction. They are circular, to a radius of 100 ft., and the gun ports are either 24 or 26 ft. apart.

Treating each as composed of an inner structure, and an armoured wall, as in the other forts, the former—or skeleton, as we got to call it in the course of erection—consists of the following parts:

First there is a circular base-plate 2 in. thick, and about 3 ft. wide, sunk into the masonry, and going completely round the fort. In this base are slotted large holes to take the feet of upright armour bars which back the armour plates in front of the guns.

Next come the lower pier casings, 11 ft. 9 in. and 12 ft. 9 in. by 7 ft. 6 in., made of $\frac{3}{4}$-in. plate, very strongly put together, and filled with concrete. Into the upper parts of these piers are set the ends of solid bars, which have to carry a part of the load of the floor above.

Next above these lower piers is a ring of 3-in. plate going all round the fort. It is slotted with holes, and the upright bar supports, already mentioned, are threaded through them.

* *Notes of Lectures on Iron Fortifications*, Chatham, 1875, p. 20.

On this 3-in. plate the front ends of the radial girders of the upper gun floor rest. Their rear ends are carried by box girders bearing on the masonry piers of the fort. Between the radial girders are the arch-plates, which complete the floor.

The front ends of these four girders are secured to a continuous curved plate standing on edge.

It is to be particularly observed that no part of this floor structure is fastened to the 3-in. plate of which I have been speaking. It merely rests on it, and the surfaces are free to slide if necessary. The object of this provision is that if the front armoured wall should be heavily battered, the risk of the racers of the upper guns being thrown out of position thereby should be reduced to a minimum.

The construction of the parts of the skeleton which intervene between the lower and upper piers demanded especial care, as these partake of necessity of the character of a joint, and it was of the utmost importance that this joint should not be a rickety one.

The construction of the piers and framework of the upper tier is, generally speaking, a repetition of that of the lower casemates, except as regards a few particulars which I need not mention here.

The armour bar supports are in one length from the lower floor to the roof, where they pass through another continuous ring $1\frac{1}{2}$ in. thick.

The pier casings are filled from top to bottom with Portland cement concrete.

The safe load of the upper gun floor, and of the roof, is equal to a mass of concrete 10 ft. thick laid all over it, which is equal to half a ton on every square foot.

Next, with regard to the armoured wall. This, it will be seen, is in three thicknesses. The inner ring is all 5 in. thick, and there is 1 in. of wood and Portland cement between it and the skeleton structure. It consists of two tiers of plates and two rings of armour bars, and is bolted to the inner structure and to the piers. The frames round the ports are $2\frac{1}{4}$ in. thick, and are exactly like those at the Portland Fort.

The plates of the next or middle thickness all stand on their ends, and are 22 ft. 6 in. long, reaching from the granite base to the level of the roof. The plates in which the ports are formed are 7 in. thick (each weighs 18 tons), the rest are 5 in. thick. This thickness is bolted to the inner plates. The plates in the outer thickness are all 5 in. thick, and are in two tiers of about 11 ft. each. They are bolted to the middle plates. The intervals between the armour plates are filled with concrete, except at the port frames, where there is wood.

At the level of the top of the lower front plates there is a gallery all round the outside of the fort.

The weight of ironwork in each of these forts is as follows:

		Tons.	Tons.	Total.
Skeleton	per gun	50 =	2,450	6,214
Armoured wall	,,	75 =	3,764	

Strengthening plates will probably be provided for the lower batteries of these forts so soon as any number of ships of foreign powers shall be armed with guns equal in power, say, to our 80-ton and 100-ton guns. The masonry on which these batteries stand will then require a corrresponding addition of strength, for which provision was made originally by leaving an offset on which armour plates can rest, and holes have been formed in the masonry for armour bolts.*

Turrets on Sea Forts.

Each of these sea forts at Spithead, Spitbank, and Plymouth is prepared for the addition hereafter of turrets on their roofs to carry two of the heaviest ordnance in each. The Spithead forts to have five turrets each, the others two each.

Mantlets.

Every gun mounted behind iron protection is to have a suitable mantlet made of rope-work for the three-fold object of deadening the effect of vibration caused by shot blows on the exterior, of stopping splinters driven off from the iron itself and bullets and fragments that may enter the port, and of keeping out smoke.

As hemp rope is liable to catch fire on the discharge of the gun, it is washed with a solution of chloride of calcium, which renders it completely uninflammable. Professor Abel helped us with his valuable advice on this point.†

Turret on Dover Pier.

I have now come to the last of the works to be described—namely the turret, for two 80-ton guns, now on the point of completion, at the extremity of the Admiralty pier at Dover. (*Plate* XI.)

* *Notes of Lectures on Iron Fortifications*, Chatham, 1875, pp. 20–3.

† *Ibid.*, p. 23. All mantlets are now made of what is called 'paunch matting,' unstranded 6-in. rope being principally used for the purpose. The larger parts are double, one layer being worked with a right-handed and the other with a left-handed twist, to prevent the curling up of the mantlet, which otherwise is very troublesome. The double 6-in. matting weighs 13 lbs. per foot superficial, and that area takes about 11 ft. of 6-in. rope.

The work to carry this turret consists of an enlargement of the outer end of the pier, as at present completed. The foundations are laid at a depth of about 7 fathoms below low water mark, and the guns will be at a level of about 33 ft. above high water. The structure, therefore, from the bed of the sea to the guns is about 95 ft. high.

Speaking in general terms, the turret consists first of a live ring, and rollers of steel running on a path of steel laid on a massive cylinder of masonry. On this live ring runs a structure of iron framework, of the form shown in the *Plate*, weighing about 240 tons. This framework contains the gun chamber, which is protected by three thicknesses of 7-in. armour, with two intermediate thicknesses of 2-in. plates, making together a weight of about 460 tons. If to these weights be added that of the guns, carriages, and the slides on which they will stand, the total running weight will be about 895 tons. This will throw upon each of the 32 rollers of the live ring a pressure due to about 28 tons. The outside diameter of the turret is 37 ft., its internal diameter is 32 ft., the interior height of the gun chamber is 8 ft. 8 in., the height of the turret armour is 9 ft.

It will be seen that a massive central casting is first held firmly down to the masonry, and that inside this there is a thick cylinder of hammered Bessemer steel surrounding the built-up wrought-iron cylinder, which forms the centre of the turret framework. I draw attention to this part, because, of course, the shock of blows on the turret walls, or more strictly speaking the unabsorbed part of it, ultimately comes to this part, and it has received especial consideration on that account. The framework is generally of wrought iron.

The roof of the turret is of strong splinter-proof construction. Over each gun there is a part of the roof which is removable, to admit of the gun being got in and out, and a part is made of open bars to allow a current of air to clear off any smoke that may enter the turret. The gun ports admit of 7° of elevation, and 2° of depression; the turret is capable of all round fire. The glacis outside the turret is supported by a ring of armour plates on edge, 5 in. and 3 in. thick, on a strong circle of 2-in. plating. The muzzles of the guns are brought inside the turret and depressed to an angle of 14°, for loading, which will be done under the glacis by steam gear, but into the arrangements for that I shall not here enter.

The turret is turned by a pinion on the vertical shaft shown working into a large ring with steel trundles, secured to the framework, the power being given by a set of main engines capable of working up to 300 h.p., and auxiliary engines of 45 or 50 h.p. For the working and loading of the guns there will be another engine of about 30 h.p.

All the engines and the boilers are in the lower part of the battery some 30 ft. below the guns. The magazines are at nearly the same level as the engines, and the shell stores at a higher level.

There will be a system of communication, by signal and speaking, from the gun chamber to the engine room, and throughout the battery.

POSTSCRIPT.

The above completes the subject of the Lecture delivered at Woolwich.

I did not think it necessary on that occasion to say much about the guns of *new type*, which the European Powers have been for some time past so busy in preparing for the armament of their fleets and coast batteries, or about our own new long breech-loading guns, which will assuredly have a powerful influence in the future upon all questions connected with armoured protection, but it may be well in reproducing this Lecture for our *Professional Papers* in 1882, to add a few words on these subjects.

In Volume IV. of the *R. E. Professional Papers* (Occasional Series), Paper XII., I gave a brief notice of what I then (1880) knew concerning the subject of the 'Increasing Power of Battering Ordnance' in this country and on the continent.

So far as I am aware, the grouping of foreign guns in comparison with our own, which I then gave, may be taken as still holding good generally; but of course, until all problems connected with the reliable working strength of these new guns depending upon the material of which they are made, as well as upon many points of constructive detail, the production of the powder for use in them, and the best material and proportions of the battering projectiles which they are to fire, have been settled, no exact conclusions can be drawn as to their ultimate powers.

Speaking generally, it may be said that the tendency in recent gun-making, for battering purposes at any rate, has been towards a reduction of calibre for a given weight of gun, and with it a greatly increased length of bore in terms of calibre has been necessary, in order to make up the required capacity for the expansion of the gases of the very large charges of powder used. With these excessive charges occupying a great length of bore, violent action was at first found to take place, and the practical remedy for this has been the introduction of slow burning powder. I believe the forms of powder to give the best rate of combustion for the different natures of the new type guns have scarcely yet been determined, and there are still some formidable difficulties connected with the erosion of bore to be met; but whatever may be the ultimate result of all this, we have already some extremely powerful breech-loading guns, which, when introduced into the service, will largely improve the armaments of our ships and shore batteries.

I am glad to say also that the question of the best proportion of weight of battering projectile to calibre is now being duly considered with reference to the new guns, and that there is a prospect of the value of $\frac{w}{d^3}$ being somewhat raised, because upon this depends the extension of the effective range of these guns for the attack of armour.

I wish I could add that the problem of producing a suitable projectile for use in the new guns against steel armour is any nearer its solution than when I last noticed the subject; experiments with steel projectiles are still under consideration, but hitherto very great difficulty has been experienced in turning out large projectiles of a temper suited to the perforation of masses of steel when striking with high velocities.

Whatever may be the effect of making the new type guns entirely of steel, according to the system adopted on the continent, or of steel ribbons surrounding a central tube, as being tried by Sir W. Armstrong & Co., the increase of battering power per ton of gun's weight already obtained is very remarkable.

Thus, our new 6-in. gun of 4 tons is almost as good an armour-piercer as the service 9-in. 12-ton gun. The new 8-in. of 12 tons will perforate equally with the service 11-in. 25-ton gun. The new 9·2-in. of 18 tons will be equal to our present 12·5-in. 38-ton gun, and I believe both the French and Germans have guns of from 70 to 75 tons weight which are superior in power to our 80-ton and 100-ton guns.

With this before us we must expect that, in a very short time, our own as well as foreign men-of-war will carry very much more powerful armaments than they have up to the present time.

With regard to the effect of these changes upon the armaments of our own coast defences and the batteries at our fortresses abroad, there is this to be said, that thanks to the adoption at last of breech-loading ordnance, we can take full advantage of the new weapons.

Wherever a 12·5-in. 38-ton M.L. gun is now mounted behind an armoured wall or shield, there a 12-in. 43-ton B.L. gun can be substituted for it; and so could the 10·4-in. of 26 tons. The 9·2-in. B.L. gun, of 18 tons can take the place of the 11-in. 25-ton and 10-in. 18-ton M.L. guns; the 8-in. B.L. gun of 12 tons, that of the 9-in. M.L. 12-ton; the 6-in. B.L. of 4 tons, that of the 7-in. 7-ton M.L. gun, and so forth.

These substitutions will involve but little alterations to the works themselves, beyond, in the case of the heavier B.L. guns, providing for the largely increased force of recoil.

When the 12-in. 43-ton gun was first produced in 1879, it became apparent that the necessarily restricted recoil of such a gun when firing a 714-lb. shot with a muzzle velocity of upwards of 2,000 ft. per second in a casemate, could not possibly be controlled under the ordinary conditions of the service carriage and platform, and therefore the officers employed in the Inspector-General of Fortifications Branch contrived another arrangement for meeting the recoil. This consisted of two upright beams attached to the front ends of the platform, and carrying trucks at their top and bottom ends, which bore against the front side of strong racers in the floor and roof of the casemate. The trunnions of the gun were set in blocks, forming the head of the pistons of two hydraulic presses, which resisted the recoil by direct thrust. By this means all tendency in the gun to jump was obviated; and, indeed, all the other difficulties attending excessive strain of recoil were overcome. Subsequently this arrangement was somewhat modified in the Royal Carriage Department, by using two pulling buffers close under the trunnions of the gun, and attached to the upright beams instead of the thrust-presses behind the trunnions, and by otherwise altering the arrangement in detail.

This method of mounting has come to be called the 'yoke' principle.

It remains yet to be seen whether guns of less power, such as the 10·4-in. of 26 tons can be efficiently mounted in a casemate on any other plan than the 'yoke.'

Beside the infinite advantage of being thus able to strengthen the armaments of our existing casemated forts, with but little alteration to the works themselves, which the introduction of breech-loading leads to, and without which we should have been for ever restricted to our present armaments, there is another decided gain in the facility with which heavy breech-loading guns can be mounted in revolving turrets and cupolas.

It has long been laid down that a gun beyond a certain weight (which may be taken at from 40 to 50 tons) cannot be efficiently mounted in an exposed position in any other way than in a turret, and as the cost of turrets increases in a very high ratio with their size, anything that tends to a reduction in the diameter of turrets must be of great importance to the service; and this effect certainly results from the use of B.L. guns. Taking it in another light, there is the advantage that in a turret of given diameter and cost a much more powerful and efficient breech-loading gun can be mounted than with the muzzle-loading principle.

One more point remains to be noticed while upon the subject of breech-loading ordnance. Those who have given their attention to the question of mounting guns in coast batteries placed at no great elevation above the sea level, must have discovered how difficult it is to arrive by ordinary methods at any satisfactory arrangement when a great lateral range of fire is demanded. Beside the obvious disadvantage of the open barbette system in these days of accurate shell fire and of machine guns, owing to the liability of the gun, its mountings, or its detachment of men to be disabled, there is a new objection to it on the score of risk attending the handling of the largely increased charges of powder that will be used.

Neither by the muzzle nor by the breech has any satisfactory plan of carrying on the operation of loading under safe cover been arranged. Side-loading, rear-loading, under front parapet-loading, have all been devised, and some of them have been tried, but without much success. The case of the 100-ton guns about to be mounted at Gibraltar and Malta, and that of some 10-in. 20-ton guns supplied by Sir W. Armstrong & Co. for the South Australian Government, are the most recent instances of attempts to obtain satisfactory side-loading. Whatever may be thought of the success of these arrangements as they stand, there can be no doubt that had a much more extended lateral range of fire been necessary at these places, the systems there adopted would not have been admissible.

On the ground of extreme costliness, turrets, or even turntables behind curve-fronted armoured walls (such as those for 38-ton guns at Gibraltar and Malta), must in the great majority of cases be dismissed from consideration; but for breech-loading guns a cupola has been contrived which for extended fire gets over most of the difficulties attending other systems.

This cupola has very sloping sides, and is made for one gun only. It covers all but a certain length of the chase of the gun, and affords room inside for loading at the breech, the ammunition being brought up through the floor of the cupola. It is placed behind a low parapet which affords protection up to nearly the level of the sill of port, and is covered by merlons on the right and left as far as the line of fire will admit. For guns up to the weight of about 30 tons, one of these cupolas can be worked by manual power from the basement.

A cupola of this kind designed to mount a 10·4-in. 26-ton gun is now in course of construction for trial both as regards the working of its own gun and its resistance under the fire of hostile guns.

While thus speaking of the numerous advantages which this new type of ordnance seems to present, we must not of course, on the other hand, shut our eyes to the certainty that in a very short time the powers of the European fleets will be largely augmented by the use of similar guns, and that this entails upon us the serious obligation of at once setting to work to strengthen our existing coast defences to a very considerable extent.

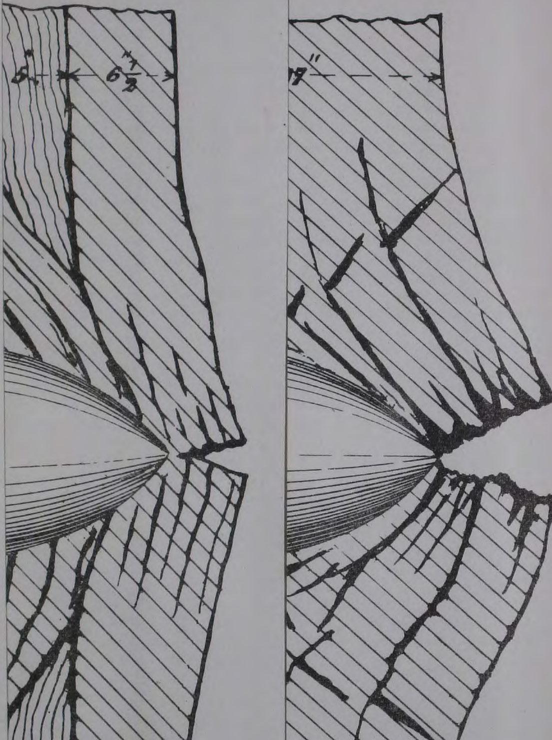
The questions thus involved are too large to be entered upon here. All that can be said on this occasion is that the leading idea which has been present to our minds throughout the operations upon the armoured protection of these works has been that there is no finality to be reached in matters of gunnery, and the consequence is that the system of construction which has been employed in them is more favourable than any other to the further addition of strength.

Beyond the considerations of expense involved, there will really be no obstacle to the strengthening of our present armoured walls to almost any required degree.

May, 1882. T. I.

NOTES ON A

Plate I.



SHOT