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J. Holland Lt R.E.

PROFESSIONAL PAPERS

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CONTENTS OF VOL. I.

No. 1.

No. 2.

No. 3.

No. 4.

N.B.—*The following Papers, published in* 1876, *were not printed uniformly, nor paged consecutively, and are therefore not included in the present Volume, but bound together as an Appendix to it.*

The Campaign in the Malay Peninsula, by Lieut. H. B. Rich, R.E., with four plates.

Field Works, from a Tactical Point of View, by Lieut.-Col. H. Schaw, R.E.

Explosive Agents, with Special Reference to their Application to Industrial Purposes, by F. A. Abel, Esq., F.R.S.

LIST OF PLATES.

ERRATA.

Page 15, last line, for *rain* read *range*.

„ 17, second line, for *Service Sights; a calculation which*, read *Service Sights with calculations, which*

„ 135, top line should come after present third line, *No. 3 carries—*

„ 135, line 25, for *timber piece* read *timber pier.*

PREFACE.

The completion of the 4th Number and the 1st Volume of the *Occasional Papers*, published by the R.E. Institute, and the commencement thereby of a new series of the *R.E. Professional Papers*, seems a fit opportunity for a brief review of the history of our professional publications.

The *Professional Papers* were commenced in 1837 at the suggestion of the late Sir William Denison, then a lieutenant, who, at the request of a meeting of the officers of the Corps, undertook the duty of editor, and performed this duty until 1847, when he was appointed Lieutenant-Governor of Van Dieman's Land (Tasmania). Eight quarto volumes had then been published, and so successful were they considered to be, that a piece of plate was presented to Sir W. Denison by the subscribers, with the following inscription :—

"Presented by his Brother Officers who attended the meeting of the 23rd September, 1846, to Captain Sir William Denison, Royal Engineers, as a token of grateful remembrance, that to him alone they are indebted for having originated the diffusion of individual experience by means of the *Professional Papers*, which he has continued to conduct for a period of ten years, until he was appointed to the Government of Van Dieman's Land."

The late Sir Henry James, then Captain James, edited the 9th Volume for Sir W. Denison, and Colonel Lewis and Captain J. Williams were appointed joint editors for the future, and were requested at the Annual Corps Meeting, held on the 1st February, 1847, to submit a plan of publication to an adjourned meeting, which was held on the 23rd of the same month. At this meeting it was determined to undertake two separate and distinct publications; the one to be of large octavo size and to be called the *Corps Papers*, to comprise subjects which might be of little interest to the public, or to civil engineers and architects; the other to be a continuation of the existing *Professional Papers*, and to embrace matters of general interest to the public, the civil engineer, and architect, as well as to the military engineer. The *Corps Papers* were to be published by subscription, but the *Professional Papers* were to be placed in the hands of the publisher, Mr. Weale, with certain privileges to the libraries and officers of the Corps in the supply of copies.

During the next three years the joint editors published three numbers of the *Corps Papers* which formed one volume, and Volume X. of the *Professional Papers*; but whilst the supply of matter for the *Corps Papers* was ample, that for the *Professional Papers* was very insufficient, and the publisher declined to continue the work on account of the expense.

At the Annual Corps Meeting held in February, 1851, it was therefore determined :—

1. That the quarto form should cease to be published.

2. That the octavo form should be continued, comprising the objects of both works.

3. That contributions should be confined to the Royal Engineers, and the Engineer Department of the East India Company's Service.

4. That the title of the work should be, under the new form, *Professional Papers, New Series*, and termed, "Papers on subjects connected with the duties of the Corps of Royal Engineers," contributed by members of the Royal and East India Company's Engineers, and edited by a Committee of Royal Engineers.

5. That the new work, under the above title, should be open to the public, and bound with green to represent the quarto volumes in a smaller shape.

Major-General Lewis and Captain Williams continued to act as joint editors until 1854, when Captain (now Major-General) J. P. Bainbrigge succeeded them, and carried on the publication until 1861, ten volumes of the new octavo series having then appeared.

Captain (now Major-General) C. S. Hutchinson was then appointed editor; in 1872 he issued an index of all papers published from the commencement in 1837, and continued ably to conduct the *Professional Papers* until the close of last year, when volume XXIII.

was published, and another change in the form of these publications occurred.

On the establishment of the Royal Engineer Institute, in 1875, the professional publications of the Corps devolved on its Committee, in accordance with the report of the Committee upon the utilization of the R.E. Institute, which was approved by the Annual Corps Meeting held on the 22nd May, 1875; but a very widely expressed wish for a change in the form of the *Professional Papers*, led, in the first place, to the appointment of a Committee, composed partly of the members of the Corps Libraries and Professional Papers Committee, and partly of members of the Institute Committee, to consider the whole subject of the Corps publications.

This Joint-Committee recommended:—

1. An annual publication, similar in character to the existing *Professional Papers.*

2. *Occasional Papers*, for subjects of pressing interest, translations, memoirs, essays, &c.

3. The *R.E. Journal*, for subjects of social and general, but ephemeral interest.

It should here be stated that, in 1869, a small monthly paper called the *R.E. Journal* was established, giving a list of the officers of the Corps, with their stations and movements, and containing matters of general interest to the Corps. This periodical, it was arranged, that the Institute should take over.

The Joint-Committee had considerable difficulty in coming to a conclusion as to the best size for the publications under heads 1 and 2. On the one hand it was urged that the size of the *Professional Papers*, viz.,—large octavo, was inconveniently large, and that ordinary octavo was a more convenient size. On the other hand, there was no doubt that, for a publication largely illustrated by diagrams, the large octavo had great advantages. On the whole, however, the Committee considered that there was a preponderance of advantages in favour of ordinary octavo.

The Committee of the Institute, probably having in mind the difficulty experienced in carrying on two such similar publications as the old quarto *Professional Papers* and the *Corps Papers*, which resulted in the discontinuance after a short time of one, came to the conclusion to recommend to the Corps at the Annual Meeting, held on 26th May, 1876, to discontinue the *Professional Papers* as then published, and that the following should be the publications of the R.E. Institute:—

1. *Occasional Papers*, on subjects of scientific interest, to be published quarterly, should there be sufficient matter to justify it.

2. The *Royal Engineer Journal*, to contain subjects of general and social interest as at present, and to be published monthly.

This recommendation was adopted at the Corps Meeting, and during the autumn of 1876 three *Occasional Papers* were published separately in pamphlet form. During this year four pamphlets, each containing four or five papers, have been published, and these are now bound together in the 1st volume of the new series.

The three papers published in 1876 were not printed uniformly nor paged consecutively, and have therefore not been included in the 1st volume, but bound together as an appendix to it.

The change of form in the *Professional Papers* is, it will be seen, principally one of size; and the matter of each volume may be obtained either in pamphlet form, immediately on publication, or bound up, at the end of the year, uniform with the previous volumes of *Professional Papers*.

There is no reason why these *Occasional Papers* should not be made of very great service to the Corps; but for this end the co-operation of every member is necessary; and we trust that during the coming year individual officers, both at home and abroad, and especially in India, will find time to communicate many interesting results of their experiences in carrying on the work upon which they may be employed, or to contribute for the benefit of the Corps at large any useful information which they may have acquired in the course of their various duties.

In concluding this brief *resumé* of the past history of the *Professional Papers*, as an introduction to the new phase upon which they have entered, we cannot do better than quote from the preface of the late Sir William, then Lieutenant, Denison to the 1st volume in 1837.

"The number and variety of the duties upon which we are employed, while they present many obstacles to the attainment of an accurate knowledge of our profession, seem at the same time to point out a system of co-operation as the surest mode of overcoming them.

"If every individual would contribute results of his experience, however trifling, and throw his quota of information into the general stock, he might, in return, draw from that stock rules and examples for his guidance under all circumstances, deduced from the collective experience of his brother officers.

"But, to accumulate this experience, and to make it applicable to the various duties which we have to perform, the talents and industry of numbers must be brought into action, and each individual should avail himself of every opportunity of acquiring information, as well for his own particular benefit, as for that of the Corps at large.

"There is pleasure in the mere exercise of the intellectual faculties, there is pleasure in the acquisition of knowledge for its own sake, but when knowledge is combined with utility, when it is available for the benefit of others, the pleasure is infinitely increased."

ROBERT H. VETCH.

CAPTAIN, R.E.,

4th December, 1877. *Secretary, R.E. Institute.*

PART I.

TARGETS

FOR THE

TRIAL OF RECENT HEAVY ORDNANCE.

BY COLONEL T. INGLIS, R.E.

A TARGET intended for the trial of the 80-ton gun—16-inch calibre—is in course of erection at Shoeburyness, and is expected to be completed by the end of November. It will be known as No. 41 Target.

It is composed of four 8-inch rolled armour-plates, placed one behind the other at intervals of 5 inches. Each of these intervals is filled with two layers of $2\frac{1}{2}$-inch teak planking, laid crossways, and held together by $\frac{5}{8}$-inch coach-screws $4\frac{1}{2}$ inches long.

The armour-plates are all of one size, namely, 16 feet long and 10 feet wide. The finished weight of one is about 22 tons.

Each plate is held to the one behind it by a set of 3-inch armour-bolts, with a spherical nut at either end fitting into cup-shaped and coned holes in the armour.

The front plate is held on by sixteen of these armour-bolts; the second by fourteen; the third by sixteen. The fourth plate is secured to the timber structure which forms the support of the target in rear by fourteen 3-inch bolts, 4 ft. 6 in. long, which have spherical nuts on their front ends and two hexagon nuts on plate-washers on their other ends.

In the interval between the second and third plates, and near to their lower corners, are two $3\frac{1}{2}$-inch studs, the ends of which pass 3 inches into the faces of the plates. These studs are for use in holding down the target to its foundations in the manner hereafter described.

The timber structure in rear of the armour consists of two rows of 14 in. by 14 in. fir piles (eight piles in a row), strutted with timbers of the same scantling, and supported by a third row of short piles further to the rear.

This timber work is very strongly put together with $1\frac{1}{2}$-inch bolts and $\frac{1}{2}$-inch straps and plates.

The target rests, near its upper and lower edges, against timber stringers, 14 in. by 14 in. in section, placed horizontally in front of the front row of piles. Thus the timber structure is intended only for the purpose of keeping the target in its place, and will not act, in the ordinary sense, as backing to the armour.

Under the armour-plates is a mass of Portland cement concrete, in which, at a depth of about 6 ft. 8 in., are inserted large washer-plates. This concrete is weighted with a mass of old armour, and two 2-inch bent bolts, which pass over the studs inserted between the second and third armour-plates, as before described, are nutted under the washer-plates in the concrete, and thus will serve as holding-down bolts for the target.

In order to give the teak filling between the armour-plates of this target a support against lateral dispersion during the entrance of the shot, equivalent as nearly as possible to that it would receive in an actual work of armoured fortification, two spare armour-plates will be set up to the right and left of the target with their faces turned towards its ends. These plates will be kept up by timber-strutted piles, and wooden wedges will be driven in between the plates and the ends of the target.

For similar reasons a heavy spare armour-plate will be laid on the top of the target for the trial.

It may be noted that the armour-plates used in this target are about the largest that have been rolled in this country. The moulds of which each is composed weighed as they went into the furnace for the last rolling about 34 tons, and when leaving the rolls the weight of the rough plate was about $31\frac{1}{2}$ tons.

The following are the particulars of the moulds used in the manufacture of these armour-plates:—

For each plate there were made sixty-five small moulds measuring 5 ft. 4 in. by 5 ft. 4 in., and varying in thickness from $1\frac{1}{8}$ in. to $1\frac{1}{2}$ in., each mould being itself made from three piles of ball furnace-iron 2 ft. 6 in. by 12 in. by 1 in.

The small moulds were used thus:—Six piles of 9 moulds in each pile were rolled down into quarter moulds 7 ft. 6 in. by 7 ft. 6 in. by 5 in. Six of these quarter moulds were again piled in two piles, and rolled into two armour-plate moulds, each 10 ft. 8 in. by 10 ft. 5 in. by 7 in. to serve as the bottom and top moulds of the final pile. The remaining eleven small moulds were piled and rolled into an armour-plate mould 10 ft. 8 in. by 10 ft. 5 in. by $3\frac{1}{8}$ in. to form the middle mould of the final pile.

The final pile therefore was composed of two double-worked and one single-worked mould, making up together a thickness of $17\frac{1}{8}$ inches and measuring 10 ft. 8 in. by 10 ft. 5 in.

When leaving the rolls the rough plate measured about 21 ft. 6 in. by 10 ft. 3 in. by 8 in. in thickness.

Pieces taken off the ends of the plates have been broken under hydraulic pressure, and the fractures show them all to be of good quality.

The gun will be placed for the trial at 100 yards from the target, that being the least distance within which it is thought that the velocity of the shot can be taken.

The shot that will be used will in all probability be the Palliser projectile, of the denomination formerly known as the 'small capacity shell,' but now the only kind of armour-piercing projectile made for the Service. It will weigh about 1,700 lbs., including a bursting charge of about 21 lbs., and the weight of the copper gas-check with which it will be fitted, which will also weigh about 21 lbs. The length of the shot will be about 42 inches, and its head will be struck to a radius of once and a half the diameter of its body.

The firing charge will be 370 lbs. of 1·5-inch cubical powder, which, when rammed home to a length of $63\frac{1}{4}$ inches, will occupy a space in the bore equivalent to 34 cubical inches per lb. of powder.

With this charge the velocity of the 1,700-lb. shot on striking the target will not be far short of 1,500 feet per second.

It is expected that, when the effect of the above shot upon the target has been fully ascertained, the gun will be chambered to a diameter of 18 inches. After this a heavier projectile and powder charge will be used, and the power of the gun will be much increased thereby.

Another target—known as No. 40, and intended for the trial of the $12\frac{1}{2}$-inch 38-ton gun—has recently been completed at Shoeburyness, and one round has been fired against it.

This target consists of three $6\frac{1}{2}$-inch plates set up one behind the other at intervals of 5 inches.

The intervals are filled as in No. 41 Target already described.

Each plate is 10 ft. long and 8 ft. wide, and weighs in its finished state about 9 tons 3 cwt.

The front plate is held to the middle one by eight 3-inch armour-bolts, provided with a spherical nut at each end to fit cup-shaped holes. The middle plate is held to the rear plate by the same number of the same kind of bolt. The rear plate is held back to the timber structure behind it by eight longer bolts of the same diameter, fitted with spherical nuts at their front ends and double hexagon nuts on plate washers at their other ends.

The timber structure in rear acts on the same principle as that behind No. 41 Target; but it consists of only one row of three 14 in. by 14 in. main piles strutted to another row of three short piles in rear. The whole structure is kept from being driven backwards by its bearing against an old target.

The armour of the target rests upon concrete, but it is not bolted down to it.

The teak filling between the armour-plates is kept in place by old plates and wedging as in the case of No. 41 Target already described.

The first object in view in preparing this target was that of obtaining an exact measure of the power of the 38-ton gun of 12½-inch calibre, firing its Service Palliser projectile of 800 lbs., with its proper battering charge of 130 lbs. of 1·5-inch cubical powder, at the shortest practicable range. An amount of armour was therefore provided which it was thought would only just stop this shot, and the problem was so exactly solved by the one round fired on the 11th inst., that while the head and part of the body of the projectile passed through the target, a portion of the base end of it was arrested and remained in the hole.

The following are the particulars of this round (No. 2039):—

The gun was placed at 70 yards from the face of the target, with the axis of its bore strictly perpendicular to it.

The charge was 130 lbs. of 1·5-inch cubical powder.

The projectile was a Palliser Service shell, with 1½ diameter head, weighted with sand up to 818 lbs. including the weight of the gas-check.

The striking velocity of the projectile was about 1,420 feet per second, and its *vis viva* therefore was equivalent to about 11,400 foot-tons.

The shell struck fair at a point 3 ft. from the proper left of the target and 2 ft. 8 in. from its lower edge.

It made clean holes, 12½ inches in diameter, through the front and middle plates, and formed a hole of the same diameter part of the way through the rear plates, knocking off the back moulds of this plate to a depth of 4 inches, the area of injured surface in rear measuring 2 ft. 4 in. by 2 ft. 3 in. The head of the shell was picked up in rear in an entire state, the point being uninjured, and the form of head unaltered. The main part of the body, which also passed through the target, was found broken into a few large pieces. The base of the shell, with the gas-check still attached to it, remained in the target.

There was little or no buckle on the face of the front armour-plate, and a buckle of only about $2\frac{1}{4}$ inches on the rear plate. There were no cracks in the plates, and no armour-bolts were broken.

The proper left end of the target was driven back 7 inches at its lower corner and 5 inches at its top, the wooden supports in rear being crushed or displaced to a corresponding extent. One of the timber piles of the supporting structure was broken in two at a point low down, where the lower stringer pressed against it, and other parts behind the end of the target struck were more or less injured. A more exact and satisfactory measure of the energy of a shot has perhaps never been obtained in an armour-plate experiment, because so large a proportion of the work in this round is to be accounted for in simple penetration of armour, and the total energy was so nearly expended upon the target.

It may be well to mention that in firing a trial shot, before this round, against a spare 10-inch armour-plate standing at a distance of about 6 feet in front of a 4-inch plate resting against an old target, the results obtained in 1870 (*see* Corps 'Papers,' Vol. XIX., page 106), with Palliser projectiles against armour-plates with void spaces between them, were repeated in a very remarkable manner.

The trial shot was similar in all respects to that used in Round 2039, and was fired with the same charge. It pierced the 10-inch plate, but on reaching the 4-inch plate it was so completely demolished that only a small portion of it was found sticking on its face in a finely divided state, the injury done to the 4-inch plate being comparatively insignificant.

It is difficult to account for the extraordinary discrepancy between the results of these two rounds. In the one case the shot expended, effectively, work sufficient to pierce $19\frac{1}{2}$ inches of armour-plate, and in the other little more than the penetration of 10 inches of armour was effected. The balance of work in the trial round was evidently spent in the destruction of the shot itself; but why this utter destruction of chilled projectiles occurs when they attack successive thicknesses of armour separated by air spaces, it is impossible at present to say.

As some very important results have lately been obtained by enlarging the chambers of guns, whereby, without increasing the maximum pressure in the bore, great additional energy can be given to the shot, it has been decided that part of No. 40 Target shall be strengthened by an additional $6\frac{1}{2}$-inch plate before proceeding further with the present experiment.

It has been found that, with a chamber increased to 14 inches in diameter, a charge of 200 lbs. of $1\frac{1}{2}$-inch cubical powder can be fired in the 38-ton gun with the Service Palliser projectile, and that with this charge it has a muzzle velocity of about 1,590 feet per second and an energy of upwards of 14,000 foot-tons. Even in the unchambered gun it has been found that by lengthening the cartridge, so as to give the powder more room for first ignition, a charge of 180 lbs. can be safely used, and a muzzle velocity of about 1,540 feet per second given to the Service Palliser projectile.

It is probable, however, that one round more will be fired at the unstrengthened target, to compare the effect of a live Palliser projectile (bursting charge 7 lbs.) with that of round 2039, the same powder charge (130 lbs.) being used.

T. Inglis.

October 25, 1876.

The first round from the 80-ton gun—16-inch calibre—at No. 41 Target, above described, was fired on February 1, 1877.

The photographic number of the round is 2041.

The muzzle of the gun was 118 yards from the face of the target.

The projectile used was a Palliser shell with a head struck to a radius of one and a half times the diameter of the body. The head only, as is usual in these projectiles, was cast in a chill, the body being cast in sand. The exact diameter of the body was 15·875 inches. The shell was weighted with sand up to 1,700 lbs. Its capacity was equal to 22 lbs. of bursting charge, but it was determined to fill it with sand instead of powder, in order to avoid any uncertainty that might arise from the action of the bursting charge. The extreme length of the projectile was 42 inches. It was fitted with four rings of studs, 13 studs being in each ring. A non-automatic gas-check, weighing about 21 lbs., was used.

The charge in the gun consisted of 370 lbs. of $1\frac{1}{2}$-inch cube powder, which gave the projectile a muzzle velocity of about 1,510 feet per second, and a velocity at the target of about 1,496 feet. The maximum pressure in the bore, due to this charge, is supposed to have been under 22 tons per square inch. With the above velocity the energy stored up in the projectile, on reaching the target, would be about 26,400 foot-tons.

The gun was aimed at a point 6 ft. 5 in. from the proper right end of the target, and 3 ft. 9 in. from its bottom edge, but the projectile struck only 6 ft. 3 in. from the right, and 14 inches lower than was intended, or 2 ft. 7 in. from the bottom.

The shot struck the face of the armour at an angle of about $1\frac{1}{2}°$ from the perpendicular, taken in an horizontal plane, and turned a little more in penetrating the target, so that its final inclination was $2\frac{1}{2}°$ to the left, and it turned also about 2° downwards.

The accompanying sections of the target, taken in horizontal and vertical directions, through the shot mark, show the exact penetration obtained, and the rear view of the back armour-plate gives more fully the effect upon it.

It will be seen that about 11 inches of the rear part of the body of the projectile broke up in the shot-hole. The head remains entire and cannot be moved. The proportion of head thus uninjured is unusually large. The fracture across the projectile is a peculiar one, presenting an almost perfect square, with its angles on the circumference of the shot, the portions between the sides of the square and the circle being sloped towards the front of the shot by the sliding of the cast iron.

The hole in the front armour-plate is exactly 16 inches in diameter, except at its front edge, where a lip seems to have been formed on the entrance of the shot, and afterwards cut off, probably by the gas-check, which was found lying just in front of the target.

As the shot on entering the target covered half the diameter of one of the armour-bolts which secured the front-plate to the one behind it, the remains of the bolt-hole appears in the shot-mark. The bolt itself was crushed and cut into four pieces, the outer end of it, with the flattened nut still on it, being thrown out to the front.

The shot-hole is distinctly scored by the studs of the projectile.

It will be seen from the sections that the front plate is but very slightly buckled, and there is no appearance whatever of a crack in any part of it.

On looking into the shot-hole it can be seen that the second plate is dished round the shot to a depth of about 5 inches.

The teak filling between the first and second plates is of course crushed and driven back from the immediate neighbourhood of the shot; also the teak between the third and fourth plates at the end of the target, nearer to the shot-mark, has been made to protrude about $1\frac{1}{2}$ inch beyond the ends of the plates at the level of the shot.

At the top of the target nothing is to be observed beyond a gradual bend of about $\frac{3}{4}$ inch on the top edge of the third armour-plate, and one of $\frac{7}{8}$ inch on the edge of the back plate.

The effects on the rear of the target are shown in the sections and rear view of the back plate.

The cracks have been probed in parts to a depth of 4 inches, but it is probable that, for a part of their length at any rate, they extend through to the front of the plate.

The fractures in the cracks show the armour to be of good quality

The armour-bolts have performed their part in the most satisfactory manner. Several of them must be more or less elongated, but to what extent it is at present impossible to say. Excepting, of course, the bolt that was crushed by the shot itself, there is no appearance of a single one being broken.

It was a moot point whether 3-inch armour-bolts would be large enough for a structure such as this; however, it appears, from the results now obtained, that no increase in the diameter of the bolts is necessary.

With regard to the timber framing behind the target, the 14-inch by 14-inch fir stringer, against which the lower part of the back plate rested, is squeezed up to a thickness of about 8 inches behind the shot bulge; one timber pile is broken nearly half through, and another is somewhat cracked. Beyond this the supporting structure is very slightly injured.

It cannot be discovered that there has been any permanent movement of the entire mass to the rear, and, moreover, it is doubtful whether even the front of the target has been driven back from its original line.

Judging generally from the results of this round, it may be assumed that, had one of the 8-inch plates been taken off this target, the projectile would have passed completely through it, and this would probably have been equivalent to the perforation of an hypothetical target composed of one large armour-plate 21 inches thick.

It is expected that the next round that will be fired at this target will be from the same gun, after it has been chambered, with a similar projectile, and a charge of 425 lbs. of $1\frac{1}{2}$-inch cube powder, which will probably give a muzzle velocity of nearly 1,600 feet per second.

It may be useful to add that on the day on which the round in the above description was fired, a common shell, filled with sand and weighing 1,700 lbs., was fired with the same charge of 370 lbs. of $1\frac{1}{2}$-inch cube powder at an unbacked plate 8 inches thick, set up at a distance of about 140 yards from the gun.

The plate had received several rounds before, but was uninjured in the part selected for this trial.

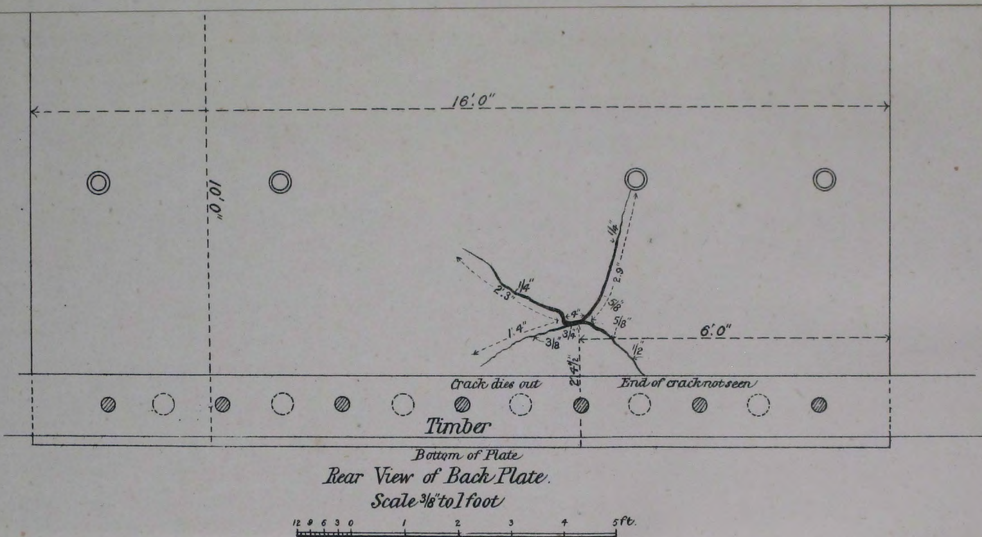
The shell passed completely through the plate, making a hole 20 inches in diameter.

As the plate was only 4 ft. 3 in. wide, it was split through to the edges, and two pieces of it were carried away by the shell.

The shell was of course broken to pieces.

T. Inglis.

10th February 1877.



Rear View of Back Plate.

Scale 3/8" to 1 foot

REPORT

OF THE

PREPARATIONS FOR LANDING OF THE 80-TON GUN AT SHOEBURYNESS.

General Considerations.

As soon as it had been decided to send the 80-ton gun to Shoeburyness to undergo a series of experimental firing, the question of the landing of such a weight came under consideration.

The largest sheers at the station are constructed to lift only 50 tons, and there is no railway within 5 miles. The commerce of the neighbourhood is carried on by barges which are loaded up to from 80 to 120 tons, and, not drawing more than 6 feet of water, are able to come over the Maplin Sands at high water and ground on the level bed at the foot of the beach. It was therefore decided that a barge of special construction should be built to take the gun, on its proof carriage, on rails, and that the gun and carriage should then be run out of the barge on to a line of railway which should be constructed on shore to meet it. The gun and carriage weighed 120 tons. A site for grounding the barge was fixed upon at the foot of the beach near the S.E. boundary of W.D. property, and for a firing platform 8 feet above it, so as to be just above the level of high-water spring tides.

Description of Special Barge.

The dimensions and construction of the barge were as follows:—

Length	85 ft. 0 in.
Breadth	27 ft. 4 in.
Height of sides amidships .	6 ft. 6 in.

Bow end circular, with gates opening outwards 8 feet wide.

The barge bottom was 4 inches thick, and composed of diagonal planking with layers of felt. Upon these were spiked timbers 12 inches deep and 12 inches wide at 4-inch intervals for 35 feet amidships, and 8 inches wide at 8-inch intervals at both ends. Three oak longitudinal keelsons $13\frac{3}{4}$ in. by $13\frac{3}{4}$ in. rested on these, the two outer ones 4 ft. 8 in. apart, carrying the rails. Two valves were also provided on each side, 1 ft. 9 in. above the bottom, for the purpose of sinking the barge artificially.

Formation of Bed for Barge to ground on.

It was contemplated that a barge with a load of 120 tons could ground with safety on the sands, as this is the usual custom, as previously stated. Owing, however, to some doubts which existed as to the strength of the bottom of the special barge, it was at the last moment decided to construct a gridiron, on which the bottom of the barge should rest when grounded. As the depth of the water even at spring tides is only 8 feet, and at ordinary tides 6 feet or less, it was necessary that the surface of the gridiron should not be higher than that of the sands. The Commissary-General, Royal Arsenal Woolwich, placed at disposal the stock of timber for sheer legs in store, from which seventeen Oregon spars, averaging 20 inches in diameter and from 70 to 80 feet in length, were selected. These spars were sent down to Shoeburyness by barge, and after being unloaded were floated to the site where they were to be used. The gridiron was then constructed as follows:—Six spars 70 ft. long were sunk in trenches 14 feet apart, 3 ft. 4 in. deep, cut in the sands at right angles to longitudinal axis of barge; the clay was filled in at the ends for 20 feet, and they were further weighted by slinging four pairs of 13-inch shell over them. The remaining eleven spars were placed in trenches 1 ft. 8 in. deep and 1 foot apart and parallel to longitudinal axis of barge. Their under sides rested on the six spars sunk transversely, and they were secured to them by jagged staples driven in and connected by short lengths of chain passing over them. They were further weighted by slinging three pairs of 13-inch shell over them.

In order to get as level a surface as possible with such large baulks (which were not allowed to be cut or adzed), the six transverse spars were placed with their butts and tips alternately. The eleven longitudinal spars were placed with their butts seawards and their tips towards the beach. In this manner a barge bed 29 feet wide and 80 feet long was made, and it was marked by guide piles—viz. three double piles for the starboard side of the barge to make fast to, and a single pile on the port side near the bow.

A mooring, consisting of an old gun weighing 30 cwt., was laid down about 100 yards seawards for the barge to haul out upon.

Railway up Beach &c.

At the foot of the beach, a short concrete jetty was made, 20 ft. long, 9 ft. wide, and 3 ft. 6 in. deep.

Between the jetty and the end of the gridiron were two short piles driven 6 feet into the ground and 4 ft. 8 in. apart from centre to centre. It was arranged with the barge builders that the gun should be delivered at a height of 2 ft. 6 in. above the bottom of the barge, the rails being left to be supplied at Woolwich. These piles were driven to the level approximately and were intended to take the first weight of the load before it reached the edge of the concrete jetty. Between the concrete jetty and the firing platform the line of rails was laid on the beach at nearly its natural slope, viz. 1 in 12. The rails were of steel  weighing 86 lbs. to the yard, and were dogged to sleepers 10 in. by 5 in. laid longitudinally and spiked to similar sleepers laid transversely at 2-foot intervals.

The firing platform* was 30 ft. long, 9 ft. wide, and 5 ft. deep, constructed as follows:—

Foundations of Portland cement concrete 16 inches deep. Brickwork in Portland cement with hoop iron bond 1 foot thick. A layer of sleepers 9 in. by 10 in. by 5 in. laid transversely, two 12 in. by 12 in. timbers laid longitudinally 4 ft. 8 in. apart, carrying two iron  girders 12 inches deep, 7-inch flange, to which the steel rails of solid section  and weighing 105 lbs. to the yard were riveted. The girders were tied together by six iron rods, $1\frac{1}{4}$-inch diameter, and were secured to the longitudinal timbers by $\frac{5}{8}$-inch coach-screws through their flanges and through oak packing 1 inch thick. Brickwork in Portland cement was built up all round the girders and up to underside of rails. The recoil line was of similar construction to the line up the beach and was 80 feet in length.

To convey the cartridges and projectiles to loading stage at the muzzle of the gun, a line of railway, 18-inch gauge of Ashantee rails was constructed, and the projectiles travelled on a bearer and the cartridges in a covered truck made at the Arsenal to suit the gauge. A temporary magazine was erected at the top of the bank, which was about 17 feet above the firing platform. A Gibraltar gyn was erected close to the edge of the bank, and the truck and bearer were lowered down the incline of the tramway, which was 1 in 6, by the windlass attached to the gyn.

* This platform stood 43 rounds very well. The girders and rails were shaken, and some of the rivets were sheared. The rail on the right side of the gun was cracked across in four places; but no further injury resulted. The platform is still perfectly fit for firing from.

Berthing of the Barge.

The barge containing the gun arrived off Shoeburyness after dark, having been delayed in the Thames by a thick fog, and grounded on the sands a few hundred yards off the berth prepared for her. Next day, about midday, without the aid of the steam tugs which towed her down the river (and which could not be got to float so soon), by the aid of the moorings and piles, she was hauled bow forwards without difficulty into the required position over the gridiron, holding on lightly to the guide piles.

It was then decided not to wait for the tide to recede, but to sink the barge artificially by opening the valves. This was done; but the result was not quite satisfactory, as she began to heel over on the port side, and had the water been deep enough she would have capsized. On touching the gridiron on the port side she gradually righted and was found to be well berthed.

As soon as the tide receded sufficiently, the leaves of the semi-circular gates were first slightly raised on their hinges, to clear the piles at the end of the jetty, and then thrown back outwards, resting against the sides of the barge.

The distances from the ends of the shore rails to those in the barge were then measured, and smiths set to work to cut lengths of rails by means of a field forge on the beach.

A connecting bridge was then made between the shore line and the barge, by placing sleepers transversely on the longitudinal spars of the gridiron and packing up till the height of the longitudinal timbers carrying the junction rails was reached.

The connecting piece was made in $6\frac{1}{2}$ hours. The length of time was owing to the smiths having to wait till the rails cooled naturally after the heat, as they had to be drilled for fishplates, and had artificial cooling been resorted to the metal would have become too hard to drill. The men were also working in the dark.

Hauling Gun and Carriage up to Firing Platform.

The hauling apparatus consisted of two 5-ton winches, which were placed on the top of the bank above and behind the recoil line, so as to insure a direct lead. The height of the bank above end of recoil line was 14 feet. The distance from the winches to the gun on the barge was 90 yards, and the distance to be travelled by the gun 50 yards, of which 30 yards was on an incline of 1 in 12. The total weight to be hauled up was 127 tons. The falls were of inch chain, and were passed through two snatch blocks attached to the gun-carriage.

The slack of these falls was taken up by two 2-ton winches placed behind the larger winches. Chain-stoppers were provided to be used during the process of shifting the fall along the barrel of the windlass. They were made of gun-metal blocks recessed to fit the chain links, and turned to fit into an iron thimble. These stoppers had previously been tested up to a strain of 12 tons each.

In the operation of hauling, 40 men were employed on the 5-ton winches, and 40 men on the 2-ton winches. These men were relieved at intervals of about 15 minutes. The time of hauling was $2\frac{1}{4}$ hours, including stoppages from all causes. An attempt was made during the process of hauling to increase the speed at the expense of the power, by racking the two returns of each fall, but the work on the winches was found to be so heavy that it was not persevered with.

M. Lambert,
Major R.E.

DESCRIPTION OF THE PRINCIPLES

OF A

SYSTEM OF SIGHTING,

AS APPLIED TO TELESCOPES AND TO THE SERVICE SIGHTS OF THE PRESENT DAY.

By Captain L. K. Scott, R.E.

With the present system of 'sighting' no gun will fire correctly, leaving out the question of rifling and wind, unless certain conditions are fulfilled, viz. that the plane on which the gun wheels rest be truly horizontal, or, in other words, that the plane containing the sights be vertical, and that a correct line of 'sight' be taken. These conditions hardly ever obtain in practice, more especially with field guns, because their positions are constantly varied, and they rarely, if ever, have a level platform, and consequently the sight being inclined the shot deviates and falls short. Another source of error is the difficulty experienced by unpractised men in taking a correct aim, which of course regulates the direction of the axis of the piece. Even if a gun stand with its wheels level on a platform, if the air be still and the gunner be exceptionally well trained and clever, if the powder be perfectly even in its strength and weight, if in fact all sources of derangement are eliminated, he will still have to contend with the fact that if the sun be shining he will be liable to error from his taking the illuminated portion of the sights as his 'line of sight,' instead of taking the true line; but if one wheel be lower than another, as is almost always the case on ordinary ground; if there be a wind blowing in any direction of any strength; if the gunner be inexperienced in all the little tricks that need apprenticeship to the trade to learn; if one or all of these elements of disturbance exist, the shooting will be less true, and approximation to good shooting can only be obtained by abstruse and complicated calculations, capable of application only by

the limited few who have had the advantage of constant costly gunnery practice. Hence it is far more unlikely for the gunner to learn to shoot accurately without practice, than it is for the infantry soldier, who can keep his sight upright, because the gunner, from firing at very long ranges, has not only to allow for inclined sights, but for wind and rifling, which is no easy matter.

In order to appreciate these difficulties it is as well to explain the process which has to be gone through under the above conditions.

Suppose with wind from the left a shot goes right to the mark, the firer has to guess the amount, and to base his calculations for deflection on this unknown quantity, which are made as follows:—

Let the distance be 50 yards to the right at 3,000 yards. The firer has to remember that one second of arc makes the axis of the gun point one inch to the right or left in every 100 yards, and ∴ at 3,000 yards it will point 30 inches to the right or left, and consequently to calculate the number of minutes of deflection for 50 yards deviation, 50 must be multiplied by 36, and divided by 30 = 60 min., or 1° as the left deflection required; but as the wheels, when on the natural surface of the ground, may sink unequally after each round, another calculation must be made to allow for this defect, to ensure accuracy of fire, without which the previous one would be useless.

It is evident, therefore, that the present system of gunnery is very defective, and that some improvement is necessary. Practically speaking the present sights are in about the same state as when they were invented by Robins 120 years ago. They were then a great improvement, for before then there were no means of firing a gun at all accurately between about three or four degrees and 45 degrees. Perhaps they were quite good enough, because the old smooth bore guns of that time were extremely imperfect in their shooting, whilst their longest effective ranges were what we should now consider almost close quarters.

If then a system of sighting can be devised which will give the gunner complete command over the axis of his gun under all conditions, without the necessity of any calculations, instead of only when the wheels are level, as at present, and then only to a limited extent, it certainly ought to be a great boon to the gunner, and a great saving of expense to the State. The Telescopic Sight and other sights proposed fulfil all these requirements, for the use of the telescope, with cross wires, removes all difficulty of aiming, and the corrections for unequal height of wheels, wind, &c., can be effected by the simple turn of a screw, *without any calculations*, and, being effected, remain perfectly accurate till a change of rain and wind occurs.

There have been three trials with the Telescopic Sight, the last of which, at 4,000 yards, was eminently successful, being as 7 to 1 as regards deflection with Service Sights. The mean error in range was 53·4 yards, which points to the fact that the powder requires improvement; and when this is done the gunner will be able to plant all the shot at 4,000 yards within a rectangle of about 5 × 5 yards. Under such accurate shooting as this no siege battery could live.

It is not pretended that extreme accuracy is required for field guns firing at large bodies of troops, yet even field guns will sometimes need the utmost perfection of shooting that can be given to them. For instance, if artillery is firing at artillery, a gun on its carriage is an extremely difficult object to hit, and the difference in accuracy will almost inevitably decide which artillery has the advantage over the other. Again, in firing at infantry behind shelter trenches, accuracy is of the greatest importance. But the difference will be still more marked in the case of siege artillery and heavy guns in coast batteries. Escarps will for the future have to be frequently breached by guns firing at considerable ranges and pitching their projectiles just over the crest of the glacis. As for coast artillery, it is at present impossible to say how far the development of firing at long ranges may reach, and it is manifest that at any range the power of being able to strike exactly the vulnerable parts of a ship can hardly be overestimated. Indeed, we expect to see such a combination of scientific means in finding the actual distance of a ship and keeping the gun carefully laid upon it as will make sure that not a single shot shall ever be thrown away. Few persons understand what the cost of each round fired from a heavy gun is. There is first to be considered the price of the powder, then that of the shot, then the cost of bringing gun, powder, and shot to the place where they are to be fired. Nor, when all this is calculated, have we arrived at the full price. To the cost of the ammunition and its transport to the place of firing must therefore be added a certain proportionate part of the cost of the gun itself. Thus, if a gun has cost £10,000—no extravagant price for the huge artillery constructed in these days (and we have not yet arrived at the end of progress in this particular)—and if the gun were calculated to fire 1,000 rounds, each round would cost £10 worth of the life of the piece.

It has been calculated that for every man slain in the Franco-Prussian war, two tons of lead and iron were expended; if by means of this system the amount can be reduced to one half per man it is worthy of serious consideration.

It has been proved that any gun in the Service on uneven ground, when sighted with this Telescopic Sight, will shoot without any calculation at least $2\frac{1}{2}$ times better than with the Service Sights; a calculation which is equivalent to the production of a gun $2\frac{1}{2}$ as accurate as any gun of the present day, and makes the invention as much in advance of the Service Sights as the rifle gun is in advance of the smooth bore.

The following are some of the objections that have been raised to the system, and the replies to them :—

1.—*That it would be impossible to correct the line of sight by turning the telescope in the direction where the shot struck, because it might not be observed.* If the shot cannot be seen, it is of no use firing; and if firing is persisted in, it will be just as likely to be accurate with the Telescopic Sight as with the Service Sights.

2. *That the time for aiming is longer.* This shows that if it takes longer to aim cross hairs on a mark which can be clearly seen with the telescope, the aim, when taken more readily with the Service Sights when the object cannot be clearly seen, cannot be as accurate; and as accuracy of fire, and not rapidity, is required, the objection fails.

3. *The gunner would require special training in the use of the instrument.* The gun being a very expensive scientific machine, turned out of the Arsenal to an accuracy of a thousandth of an inch, it is necessary and worth while to have men instructed in the use of a machine which will extract the best shooting powers of the gun, and if the advance of the age requires that a more perfect knowledge of gunnery should be acquired, instruction should be imparted; as there is no reason whatever why every gunner in the Service should not be as well acquainted with his particular nature of gun as an infantry soldier is with his rifle. It is possible and very easy to teach a man to manipulate an instrument with care, but by no means possible to teach a man to make the abstruse calculations required for accurate shooting with the present sights.

4. *The delicacy of the instrument.* The instrument is no more delicate than the ordinary binocular, and being used with field guns in combination with the existing sights, no injury short of breaking the glasses would affect its accuracy of shooting, nor would the gunner be at a greater disadvantage than he is at present in any case.

Description of Instrument.

The instrument may either consist of one part, or of two parts (the bracket and sight). *See drawing.* In the first case the bracket is screwed on to the side of the gun in any convenient position and remains on, but the 'sight' is lifted off when the gun is fired. In the second case the bracket and 'sight' together are slipped in and out of a corresponding groove cut in the end of the trunnion which exactly fits the dovetail screwed on to the back of the bracket.

The bearings in which the 'sight' rests are cut as nearly as possible in every direction parallel to the axis of the gun for the sake of convenience, and when the revolving tray (on which the telescope with its supports rests) is level, as shown by the bubble of the level being in the centre, the line of collimation of the telescope and axis of revolution should be as nearly as possible in one and the same vertical plane, and any remaining error is rectified by the deflection screw D, which gives the telescope a horizontal movement. The 'sight' is worked by three slow-motion screws, E, D, W. E is to give elevation, D deflection for 'rifling' and 'wind,' and W is to make the plane passing through the line of collimation of telescope and axis of revolution vertical (shown by level on tray having the bubble in the centre) when the wheels of the gun are not on the level. Suppose the gun is to be fired with an elevation of 20′ 19°, one wheel lower than the other, and wind from the *right*: turn screw E from left to right till telescope has been moved through an angle of 20° 19′, and give supposed required deflection of 59′ for 'rifling' and 'wind' by turning screw D to the *right*. Place the axis of revolution of sight into the bearings with the projection P under the spring S and the ball of the screw W into its receptacle under the bracket, and if the wheels are on uneven ground sloping to the *right*, level the 'sight' by turning screw W to the *right*, lay the cross wires (⊕) (which are lines scratched on glass) on the object, and see that the bubble be still in the centre when this operation is completed; lift the sight off the bracket, and fire; but if the shot does not strike the mark, run the gun up into its previous position, direct the cross wires (⊕) on the same mark (the telescope being levelled as before), and turn the telescope horizontally by means of screw D in the direction where the shot was seen to strike. Then if the telescope be again directed on the object to be hit by means of the trail of the gun and elevating screw, and the gun fired, the shot will this time go in the direction of the mark, and ever after till the range and wind change. *See Sketches, Fig.* 1.

The application of the three screws E, D, W is very easy to remember. To give elevation turn E to the right; to give right or left deflection, i.e. to turn axis of gun to right or left of object, turn D to right or left; when wheels are inclined to right or left, turn W to right or left. When W is turned to the right, the tray is pressed down in the opposite direction by means of the flat spring screwed to the brackets. When W is turned in the opposite direction, the tray is levelled by the force of the spring. In order to facilitate the 'laying' of the gun by means of the cross wires (⊕), the telescope is provided with a back sight and foresight, which allows of the firer taking a rough 'line of sight' to get the cross wires at once on the object, which operation is done during the loading, and enables him to fire just as quickly as and far more accurately than with the present mode of sighting.

It is to be understood that the present instrument, having been constructed for field guns, has been made as small and portable as possible, without any unnecessary levels, and consequently it is not intended to be used for firing at unseen objects from behind parapets. It could be so used if necessary, by placing the level on the top of the telescope and by making it capable of turning, so as to be parallel to axis of telescope, whereby the true angle of elevation could be given instead of 'angle of fire.' The screws E and D should have micrometer heads divided into sixty parts to allow of minutes being read off by the naked eye. By means of the deflection screw D, allowance is made for 'rifling' and 'wind' together; but should it be deemed advisable to be able to fire accurately in calm weather without having recourse to a trial shot (which must be always the case with the present sights), the mean angle of deviation for the particular nature of gun being estimated in the usual way (which for the 16-pounder is 2° 16′), the zero of the micrometer head could be permanently set at this angle; and if this be not approved of, the level at right angles to axis of revolution can be set at an angle of 2° 16′,* so that when the screw W is turned to neutralise the inclination of the wheels, the angle which the vertical arc will make with the horizon when bubble is in the centre of level will be 90°−2° 16′. This, however, is open to the objection that elevation is lost by inclining the sight.

For field guns, where the telescope should be used in combination with the existing sights, there is no need of any graduated arcs, nor of any level at all, because the elevation can be borrowed from these Service sights, and any further elevation necessary can be given by the micrometer head of E, and the arc can be vertically adjusted by the eye, as is done in musketry practice, or by the vertical wire of the cross wires.

To borrow the elevation from the Service sights, let us suppose that the object to be fired at be 3000 yards distant. Raise tangent

* This was kindly suggested by Major Maitland, R.A.

sight up to this distance, and aim at a small mark at a distance easily seen by the eye, and direct the cross wires of the telescopic sight, which has been carefully levelled, on a point level with this mark, but at a distance from it equal to the distance of the centre of the telescope from the line of sight of the Service sights. This process will make the line of sight through the cross wires (⊕) parallel to line of sight of service Sights.

The advantages of this instrument are as follows:—

No. 1.—An unseen object can be fired at when it is at a known lateral distance from a mark that can be seen, by the use of the deflection screw D. *See Sketches, Fig.* 2.

Suppose a dam which is to be cut is known to be 100 yards to the *left* of a church spire 2000 yards distant.

Direct the cross wires of the telescope on the church, and turn screw D to the *left* the number of minutes required to make the axis of the gun point 100 yards to the left at a range of 2000 yards, and give the angle of elevation in this case by means of a spirit level.

The allowance to be given for deflection in minutes for a lateral deflection of 100 yards at a distance of 2000 yards is calculated from the fact that 1′ of arc makes the axis of the piece point to the right or left of the mark aimed at 1 inch at a distance of 100 yards; ∴ at 2000 yards 1′ gives 20 inches lateral deflection, and consequently the number of minutes required for 100 yards lateral deviation $= \frac{100 \times 36}{20} = 180' = 3^\circ$. The above method enables the firer always to have a fixed mark to aim at. In firing at large horizontal angles it might be necessary to make an allowance for the loss of elevation, therefore a table has been calculated for this purpose.

Table of increments of elevation to be given to the angle of depression of the telescope so as to give the gun the true elevation when the axis of the telescope, instead of being parallel to, makes a horizontal angle with the axis of the piece, which are calculated from the formula, $\tan x = \tan \alpha + \sec \delta$, where x = angle to be given to telescope to give a certain angle of elevation α to gun with a horizontal deflection δ.

(*For Table see next page.*)

Angle of Elevation of Gun	δ Horizontal Angles of Deflection.										
α	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
1·0	0	0	0	0	0	0	0	0	0	0	1
1·30	0	0	0	0	0	0	0	0	1	1	1
2·0	0	0	0	0	0	0	0	1	1	1	2
2·30	0	0	0	0	0	1	1	1	1	2	2
3·0	0	0	0	0	0	1	1	1	1	2	3
3·30	0	0	0	0	0	1	1	1	2	2	3
4·0	0	0	0	0	0	1	1	1	2	3	3
4·30	0	0	0	0	0	1	1	2	3	3	4
5·0	0	0	0	0	0	1	1	2	3	4	4
5·30	0	0	0	0	0	1	1	2	3	4	5
6·0	0	0	0	0	0	1	2	2	3	4	5
6·30	0	0	0	0	0	1	2	2	3	4	6
*7·0	0	0	0	0	1	1	2	3	4	5	6
7·30	0	0	0	0	1	1	2	3	4	5	7
8·0	0	0	0	0	1	1	2	3	5	6	7
8·30	0	0	0	0	1	1	2	3	5	6	8
9·0	0	0	0	1	1	2	3	4	5	7	8
9·30	0	0	0	1	1	2	3	4	5	7	9
10·0	0	0	0	1	1	2	3	4	6	7	9
10·30	0	0	0	1	2	2	3	5	6	8	9
11·0	0	0	0	1	2	3	4	5	6	8	10
11·30	0	0	0	1	2	3	4	5	6	8	11
12·0	0	0	0	1	2	3	4	5	7	8	11
12·30	0	0	0	1	2	3	4	6	8	9	11
13·0	0	0	0	1	2	3	4	6	8	9	12
13·30	0	0	0	1	2	3	4	6	8	10	13
14·0	0	0	0	1	2	3	5	6	8	10	13
14·30	0	0	0	1	2	3	5	6	8	11	13
15·0	0	0	0	1	2	3	5	6	8	11	13
15·30	0	0	0	1	2	3	5	6	9	11	13
16·0	0	0	0	1	2	4	5	7	9	11	14
16·30	0	0	0	1	2	4	5	7	9	11	14
17·0	0	0	0	1	2	4	5	7	9	12	14
17·30	0	0	0	1	2	4	6	7	9	13	15
18·0	0	0	0	1	2	4	6	8	10	13	15
18·30	0	0	0	1	2	4	6	8	10	13	16
19·0	0	0	0	1	3	4	6	8	10	13	16
19·30	0	0	0	1	3	4	6	8	10	14	16
20·0	0	0	0	1	3	4	6	8	11	14	17

And it is used in the following manner:—

Find in column α 7°, which is the angle at which the gun is to be fired at to carry 3000 yards, and look along this line till you come to the increment 4′ as shown in the column showing 8° deflection; add 4′ to the 7°, which makes 7° 4′ as the angle of depression to be given to the telescope to produce an angle of elevation of 7° with a deflection (δ 8°).

No. 2.—The gun can be fired under cover of a parapet by means of the level; but great care must be taken that the plane passing through the axis of level is vertical and parallel to plane passing through axis of gun, because if the plane passing through the axis of level be not vertical, the gun will get too little elevation, and if it be vertical but not parallel to the vertical plane passing through axis of gun, the gun will get too much elevation.

The telescope can be used for taking aim from behind earthworks by reversing it in its bearings and by directing the cross wires on some distant object, the angle of elevation being obtained by raising the telescope. The direction of the howitzer could be maintained by a line on the platform.

No. 3.—Breaches can be made in walls with greater rapidity than formerly, on account of the improved accuracy of fire.

No. 4.—Moving objects, such as ships, can be fired at with great accuracy by a proper use of the deflection scale.

No. 5.—For night firing the elevation can be given in two ways—1st, by the spirit level; 2nd, by fixing a light at the required elevation during the day and by directing the cross wires (which can be clearly seen) on it. The direction may be given in two ways—1st, by means of the ordinary swinging scales, which would be troublesome to manage at night; 2nd, by placing gun carriage on curved rails which have been secured to the ordinary wooden platform during the day time, which method, it is believed, would be an improvement on the use of the swinging scales on account of the absence of traversing the gun after every round.

The rail platform is a moveable frame of iron, consisting of three curved rails bolted to a transverse plate, which is secured to the centre of the wooden platform by means of a strong bolt, around which the whole frame turns, so as to allow of its adjustment in any direction. The graduated curved centre rail is to allow for deflection.

The two outer rails are for the wheels of the gun, which are supplied with flanged or grooved tires to run on, and the centre one for grooved plate (fastened to the trail) to work on. The flanges of the wheels should be of sufficient depth to allow of the tire and flange to rest on the wooden platform and rail at the same time, and the depth of the grooved plate should be similarly regulated. *See Sketches, Fig.* 3.

No. 6.—Taking a correct 'line of sight' is independent of the human eye and of any practice on the part of the firer.

No. 7.—When the true elevation and deflection are found, they can always be maintained, because the telescopic sight is lifted out of its bearings without touching the elevation or deflection screws E or D.

No. 8.—The greater accuracy of the fire reduces the number of shots, and consequently the amount of transport, to a minimum.

No. 9.—The range can be accurately determined.

No. 10.—A level platform not being required, the artilleryman will be no longer in the anomalous position of being dependent upon the engineer for accuracy of fire, and considerable expense and trouble will be saved in permanent fortification.

No. 11.—The whole lateral error or deflection in firing and $\frac{7}{10}$ of the variations in range being due to defective sighting, and not, as is generally asserted, to the inequality in the strength of the powder, the power of artillery will be increased to an extent unprecedented in the annals of artillery.

No. 12.—If it be borne out by facts that this telescopic sight will make any gun in the service shoot $2\frac{1}{2}$ as accurately as with the present sights, it will be equivalent to the production of a gun twice and a half as accurate as the present gun, for the small sum of £4.

To Find the Range of Objects at Sea.

If this instrument is to be used to find the range of an object at sea from a battery, say 100 feet above the level, adjust the vertical arc vertically by screw W, turn the telescope down by screw E till the cross hairs cut the ship, and read off the distance, which is graduated, from calculations, on the exterior edge of the vertical arc; or, in order to obtain the distances to a larger scale, an arm might be attached to and revolve with the trunnion of the gun, which would read off the distances marked on the check of a carriage gun, as shown in the sketch. *See Sketches, Fig.* 4.

To Find the Range of Objects on Land by means of a Base-line.

To find the range of objects on land a tripod must be supplied which has circular graduated parallel plates with bearings similar to those on the bracket for the reception of the axis of revolution, so that the necessary horizontal angles may be observed from the ends of a measured base and the range therefrom acquired by reference to previously calculated tables.

To Find the Approximate Range without a Base-line.

To find the range by means of the micrometer-headed screw D *without the use of a measured base-line*, the breadth or height of the object or objects on which the telescope is directed must be assumed, and the angle in minutes subtended by the breadth or height of this or these objects must be observed and read off the micrometer head D, and the range by this means calculated.

For instance, suppose the breadth of six men in line be taken as twelve feet, or that of a gun as six feet between the wheels, or that of an ordinary gate into a farm or park as twelve feet, or that of a church as 100 feet. *See Sketches, Fig.* 5.

Let ab represent six men = 12 feet.

Direct cross wires on a, and measure the horizontal angle aTb by deflection screw D. Let $aTb = 3'$.

Now, since 1′ of arc at 1,200 yards (which number is taken for the sake of convenience because 1 foot = 12 inches) gives 12 inches or 1 foot deflection, and the angle subtended by six men = 3′,

∴ at 1,200 yards 3′ gives 3 feet deflection, and consequently, if we divide 12 feet, the breadth of the section of men, by 3 feet and multiply by 1,200 yards, 4,800 yards will be the range required—

$$\tfrac{12}{3} \times 1{,}200 = 4{,}800 \text{ yards};$$

or in other words, multiply the breadth or height of the assumed object in feet by 1,200 *and divide by the subtended angle in minutes.*

To Breach a Wall.

To breach a wall at 800 yards distance.

Let the elevation required be 3° for the shot just to clear the parapet of the glacis with the deflection scale at zero.

Fire 3	shots at	3°	elevation and	0′	deflection.
3	,,	3°	,,	1′	,,
3	,,	3°	,,	2′	,,
3	,,	3°	,,	3′	,,
3	,,	3°	,,	4′	,,

and so on till the horizontal cut has been effected. The cross wires must always be directed on the same spot, whether it be a fixed observable mark on the wall or any other visible point on the fortress, and the axis of the gun must be directed away from it by means of the screw D. The vertical cuts will be made in the same manner by altering the elevation by screw E. *See Sketches, Fig.* 6.

Adjusting Ring and Revolving and Reflecting Sights, which will give the Firer command over Axis of Gun under all conditions.

With reference to the principles of this system of sighting guns as applied to the above telescopic sight, which enables the firer to shoot accurately regardless of rifling, wind, or inclined wheels, without recourse to any calculation, it is shown, in continuation of the same system, how the same principles may be adapted to the existing sights and how a telescopic sight may be attached to them. With the existing sights the firer has only command over the axis of the gun when the wheels are level; when they are not level he loses that command, and is obliged to make unreliable and guesswork calculations for inclined 'sights.' If some means could be provided for keeping the sights upright under all conditions of wheels, then these calculations would be eliminated.

It is proposed therefore to place the 'tangent sight' and 'foresight' on rings capable of turning round the gun and consequently of allowing the 'sights' to be adjusted vertically, either by the eye as in musketry practice or by means of 'plumb-line' or pocket level. Each of these rings will be placed between two other immovable rings, two of which (one for 'tangent sight,' the other for 'foresight') will have a portion of arc equal to about 30° divided into the same number of divisions, irrespective of the radii of their circumferences (*Fig.* 1, *Plate* I.), so that when the 'tangent sight' ring is levelled and clamped by screw D, the number of divisions as shown on the graduated ring can be read off, and the ring of the 'foresight' can be turned round the same number and clamped, which operation will give a line of sight parallel to the axis of the gun.

Description of Plate I.

Figs. 1 *&* 2 represent end and side elevation of 'tangent sight' when it is intended to use a telescope in combination with it at long ranges.

The portion T shaded is the telescopic sight, consisting of supports in one piece, with a circular hole through it, which fits on the tangent sight, and is kept in any required fixed positions by the guides *gg*, which are elastic pieces of metal screwed down to the bed, around the tangent sight, prepared for them, i.e. (*gg*) ; for the sake of adjustment the screw holes are slotted. To the short axis of telescope is fixed an arm A, which is made to turn by a micrometer slow-motion screw M, which reads minutes, the degrees being read off an arc of 23° graduated on the support T. The 'tangent sight' is circular in form, which (being more easily made accurate and allowing of a horizontal movement being given to the telescope) is kept in any particular position by means of the collar *c*, which is clamped by screw C. The collar is secured to the metal which contains the sight by means of a dovetail, through which a screw *t* passes into the metal, as shown in *Fig*. 2. S is a screw containing a conical hole, through which the plumb-line, if used, passes.

In *Fig*. 1 the tangent sight is supposed to be vertical minus 2° 16′, which angle is the mean angle of deviation for rifling of the 16-pounder.

This inclination of the sight, however, is not necessary, because the arrow-head of the deflection scale of tangent sight should be so marked that it is as much to the left of the centre line as will give the required allowance for rifling. *See Sketches, Fig*. 7.

Fig. 3. represents end elevation of tangent sight if no telescope is to be used in combination with the field gun.

Fig. 4. represents foresight, which, by unscrewing, can be raised as high as the tangent sight has to be raised when a portion of it is covered by the support of the telescope and the screw washer is screwed in the opposite direction to clamp it in its position. The fact of being able to raise the foresight enables the firer to use the existing sights when the telescope is on the tangent sight, and of checking his aim.

There should be a sight on either side of the ring, which must be clamped by a screw in any convenient part, and a hole must be drilled through the top of the tangent ring for lubricating purposes.

Plate II.

Shows proposed 'adjustable reflecting and revolving sight,' with its principle explained in the drawing.

Method of using Sights.

Method of using sights *without calculation*, supposing the gun wheels be not on the level, and the wind be blowing from the right:—

Turn the 'tangent ring' round until the sight is level, as shown by 'plumb-line,' pocket level, or eye, and clamp it; read off the division which is opposite to the arrow-head, and turn 'foresight ring' until its arrow-head is opposite to the same division, and clamp it; remove plumb-bob, and make allowance for wind by deflection scale, and fire. If the shot goes to the *right*, run the gun up to its former position, take the same aim as before with the same deflection, and move the eye to the *left*, along the deflection scale, until the backsight and the top of the 'foresight' be in line with the direction of the spot where the shot struck. If this be correctly done the correct line of sight will be found and will hold good till a change of wind occurs. *See Sketches, Fig.* 8.

To use Telescopic Sight.

Raise the tangent sight sufficiently high (as shown by a mark cut on it) to receive the support of telescope; raise 'foresight' by unscrewing and clamp it by washer; level the sight as before; give the angle of elevation by depressing the telescope by slow-motion screw m; set the telescope by turning the tangent sight round and clamping it by screw C in such a way that it will make allowance for rifling and wind as far as can be judged, and check the elevation by aiming with the ordinary line of sight, over the tangent sight and top of the foresight; direct cross wires on the mark; lift it out of its guides, and fire.

If the shot go to the left, run gun up and aim as above described, unclamp the sight by screw C, turn telescope round horizontally into the direction where the shot fell, clamp and direct cross wires on the mark by moving the trail and elevating screw of gun. Then this will be the correct line of sight for the present conditions of fire without further calculations.

Trial of Telescope Sight.

In order to test the comparative merits of the present system of sighting and the one proposed, two trials were carried out in January 1876, with the following results:—

The practice of the *Diagrams* A, B, at 1,200 and 3000 yards, were executed under circumstances not very favourable to the development of the powers of this instrument, nor of the comparative merits of the competing systems, because the gun was fired by a most experienced and highly trained Artillery officer, who was thoroughly acquainted with the Service sights, but who had never seen the Telescopic Sight till the day of the trial.

The first trial was carried out at a range of 1,200 yards, at a target 18 ft. by 18 ft., *from a level platform*, with a strong wind from the right rear.

Scott's sight was fixed to the right side of the gun and the Service sights to the left of the same gun.

First, ten shots were fired with the Service sights; secondly, ten shots with Scott's sight. It will be observed that the first shot from Scott's sight struck the centre of the target, the second to the right of the first, the third to the right of the second, the fourth to the right of the third; but on examining the sight, which had been clamped vertically at the first round, we found that it had slipped and was considerably inclined to the right from the force of the recoil. It was accordingly readjusted vertically, and the fifth shot again struck the centre of the target, which justifies the conclusion that the deviation to the right of the previous shots was due to this cause, and not to the possible varying strength of the wind; and therefore, if the necessity of levelling the instrument before every round (which is the chief principle of Scott's sight) had not in the hurry of the moment been overlooked, the practice, I believe, would have been still better. As it is, the result is about $2\frac{1}{2}$ in my favour, seeing that the rectangle is $9\frac{1}{4} \times 7\frac{1}{2} = 67$, whereas that of the Service sights is $17 \times 9\frac{3}{4} = 165$, and this *from a level platform. The level platform* in this trial was naturally in favour of the Service sights, because, with these sights, when the wheels are not level, it is *mechanically* impossible for the gun to shoot in the required direction without calculated corrections for deflection being made after every round (on account of the level of wheels being changed from the recoil), which, as will be seen by the *Diagram* B of the second trial, are quite unreliable even with the most experienced Artillery officer. With the proposed instrument, as already stated, the gun will shoot accurately under all conditions of inclined wheels, without any calculations for the wheels or for the deviation of the shot, by the employment of a mechnical arrangement, which must be far less liable to error than the judgment of the firer.

In order to prove this, a second trial, *Diagram* B, was carried out at 3000 yards with the 16-pounder (reputed to be the worst gun in the service), at a target 9 ft. by 9 ft., the wheels resting on the natural surface of the ground sloping to the right from 1° to 10°, the wind blowing strong from the right rear. A line was picketed from the firing point to the target, and the position of each shot, as it fell on the ground, was measured at right to this line. Captain Ellis endeavoured, with all his skill and knowledge in gunnery, to keep his shots with the Service sights in line with the target by a constant change in the deflection; but the deflection with Scott's Sight remained the same throughout.

On this occasion 20 rounds were fired in all, as in the first trial, but by alternate shots, commencing with the Service sights as numbered in *Diagram* B. The elevation of the Service sights was 6° 40′ and that of Scott's sight 7° 16′, thereby showing that the axis of revolution had a depression of $7° \, 16' - 6° \, 40' = 36'$. The deflection of Service sight varied for every round, and that of Scott's sight remained 17′ throughout.

On reference to the table on *Diagram* B, it will be observed that No. 1 shot was fired with 5′ left deflection to counteract the inclination of wheels and direction of wind from the right, and it fell at a distance of 2,978 yards and 9·8 yards to the left of the picketed line.

No. 3, which is the second shot with Service sight with 5′ left deflection, fell at 2,948 yards and 9·2 yards left.

No. 5, deflection 0, 2,961 yards, and 1·6 yards left.

No. 7, deflection 0, 2,833 yards, and 4·4 yards left.

No. 9, deflection 12′, 2,979 yards, and 26 yards right. It was intended to have given 32′ deflection, which would have altered the position of this shot to 10 yards to the right.

No. 11, deflection 32′ left, which is the maximum deflection which can be given to a 16-pounder, 3,001 yards, and 9 yards right.

No. 13, deflection 32′ left and aimed off the left of target, 2,962 yards, and 2·2 yards left.

No. 15, deflection 32′ left and aimed off the left of target, 2,978 yards, and 2·4 yards right.

No. 17, deflection 32′ left and aimed off the left of target, 2,961 yards, and 13·0 yards left.

No. 20, deflection 32′ left and aimed off the left of target, 3,027 yards, and 7·8 yards left.

The increased deflection for each round clearly shows that the recoil makes the lower wheel sink more and more after each round, and consequently a fresh correction has to be made before firing, which is calculated in the following manner:—

Suppose the first shot be correctly estimated to have gone 50 yards to the right at 3000 yards, the firer has to remember that 1′ of arc makes the axis of the gun point 1 inch to the right or left in every 100 yards, and therefore at 3000 yards it will point 30 inches to the right or left; and consequently, to calculate the number of minutes of deflection for 50 yards deviation, 50 must be multiplied by 36 and divided by 30, equals 60′ or 1° as the left deflection required. But besides this, another calculation should be made for the further sinking of the lower wheel due to the recoil, without which the previous one would be useless.

The defects of the present system of sighting guns cannot be better illustrated than by contemplating the number of guesswork calculations required per gun and the confusion of fire which would take place in a battery of artillery in a ploughed field, with the wheels of the six guns at a different angle of inclination. Every round which each gun fires must always be a trial shot for that gun, on account of the ever-varying conditions of inclined trunnions after every round, which change the basis of calculation for each succeeding one, not only for its own gun but for each of the other five in the battery, and renders the present method of sighting nothing less than a system of guesswork.

There are other sources of error which cannot be allowed for by calculation, and which are dissipated by the use of a telescope.

When the sun shines from the right or left it lightens up the right or left of the foresight and the left or right of the notch of tangent sight; and the consequence is that the line of sight is taken along the illuminated portions of the sights instead of through the centre of the notch and tip of the foresight, which will cause the axis of the gun to be directed to the left or right of the object.

When the sun is vertical the aim is often taken low, on account of the reflected rays from the top of the foresight instead of the actual tip of the foresight being directed on the object.

With the proposed instrument all these guesswork calculations are unnecessary. The firer has command over the axis of his gun to within 18 inches at a mile and he can direct, by means of the cross wires, the line of sight on an object at a distance equal to the range of the gun with accuracy and constancy without any other training than in the manipulation of the instrument to be acquired by any ordinary man of intelligence.

The existing method of giving the angle of elevation to guns behind parapets by means of the quadrant is liable to great error, and should never be used when the ordinary line of sight is available, on account of the great care required for its adjustment.

1.—If the plane passing through the axis of level be not vertical and parallel to plane passing through the axis of gun when the bubble is brought to the centre (which case is very apt to occur from the platform being out of level), the gun will get *less* than the true angle of elevation.

2.—If the vertical plane passing through the axis of level make a horizontal angle with the vertical plane passing through axis of gun, the gun will get *more* than the true angle of elevation required.

With Scott's sight all these sources of error are eliminated; for by its construction it enables the firer to get the above-mentioned plane vertical and parallel to plane passing through axis of gun.

The recent experiments at Eastbourne with high-angle fire from 10′ and 6·3′ howitzers, carried out under circumstances which would never occur in practice, clearly demonstrate the futility of the present mode

FIG. 3.

Rail Platform.

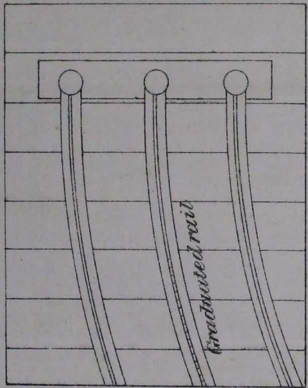
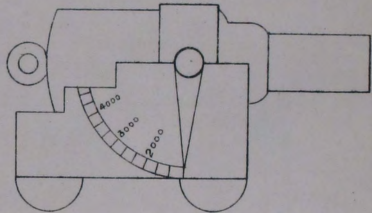


FIG. 4.



of sighting and the imperative necessity for an improved system. About 200 or 300 rounds, costing at least, when transported, £4 each, were fired, which did no material damage to the defensive works. The range was accurately measured, and the position of each shot as it fell was telegraphed back to the firing point before the next round, and the direction and elevation had the advantage of being given by means of a line of sight (instead of the quadrant) aimed at a target standing up on the casemate, which certainly would not have been placed there by the enemy.

The chief causes of the inaccuracy of fire as regards sighting are, it is believed, the following :—

1.—The tangent scale for high-angle fire being necessarily very long, multiplies very much the smallest error from a shake at the base.

2.—The distance between the foresight and tangent sight being very short.

3.—The constant shifting of the platform, which causes a change in the elevation and deflection of the piece.

For instance, the platform had gradually become sloped to the rear about 3°, and to the right about $2\frac{1}{4}$°, and the howitzer having to be laid a long distance off to the left of the mark, was consequently at an angle of inclination between the two.

SPITHEAD FORTS, PORTSMOUTH.

EXPERIMENTS ON PORTLAND CEMENT.

The following experiments were made with a view of ascertaining the effect caused by the presence, in various quantities, of particles too large to pass through a sieve of 2,500 meshes per square inch.

The cement used was manufactured by Francis, Son, & Co., Newport, Isle of Wight, weight 110 lbs. per bushel net, breaking strain 395 lbs. per square inch.

The ordinary weight of Portland cement used at Spithead varies from 104 lbs. to 120 lbs. per bushel, and the average breaking strain is about 385 lbs. per square inch.

After sifting the cement, a residue of $\frac{23}{100}$, by measure, was left in the sieve.

A quantity of this residue was crushed or ground until every particle of it passed through the sieve.

There were thus:—1st, Sifted Cement;
2nd, Residue, whole;
3rd, Residue, crushed;

which were combined in the proportions shown in the table, and gauged, with as little water as practicable, into briquettes, which remained in the moulds 24 hours, and were then taken out and immersed in water for 7 days longer, making in all 8 days between the gauging and breaking.

The residue, which is very dark—almost black—and extremely hard, appears to consist of the more highly burnt portions of the material, which have, by their hardness, withstood to some extent the action of the grinding machinery.

The results shown in the table are, in each case, the average breaking strain of 10 briquettes.

The inference to be deduced from these experiments appears to be that the strength of Portland cement is not materially affected by the presence of from 10 to 30 per cent. of coarse particles.

Results of Experiments to ascertain the Effect caused by the Presence, in various proportions, of Coarse Particles in Portland Cement.

No. of Experiment	Description of Material		Breaking strain per square inch in pounds	Remarks
1	100 parts sifted cement	0 parts residue . .	344·6	
2	90 ,, ,,	10 ,, whole .	375·0	
3	90 ,, ,,	10 ,, crushed	357·9	
4	77 ,, ,,	23 ,, whole .	395·0...	As received from contractor without sifting.
5	77 ,, ,,	23 ,, crushed	345·9	
6	70 ,, ,,	30 ,, whole .	365·1	
7	70 ,, ,,	30 ,, crushed	364·0	
8	50 ,, ,,	50 ,, whole .	343·2	
9	50 ,, ,,	50 ,, crushed	324·0	
10	30 ,, ,,	70 ,, whole .	273·9	
11	30 ,, ,,	70 ,, crushed	334·7	
12	10 ,, ,,	90 ,, whole .	84·0	
13	10 ,, ,,	90 ,, crushed	353·3	
14	0 ,, ,,	100 ,, whole .	0·0	
15	0 ,, ,,	100 ,, crushed	350·6	

C. de B. Carey,
Lt. R.E.

PAPER V.

ON THE STRENGTH OF

BESIEGING ARMIES.

By Lieut-Colonel H. Schaw, R.E.

In considering this subject, as it annually becomes necessary for me to do in the course of my lectures at the Staff College, it has appeared to me for some years past that there is an error in the mode of calculating the number of men required for a siege, which has been adopted in our recognised military text books.

Our data on the subject are taken from the notes to the *History of the Sieges in the Peninsula*, by Sir John Jones. The principles he lays down are the following. The guard of the trenches should be three-fourths of the garrison, and it should have three reliefs, or, in other words, the infantry force required for this duty should be $3 \times \frac{3}{4}$, or $2\frac{1}{4}$ times the total force of the infantry of the garrison. The working parties should have four reliefs, and should be sufficient in number to make about 3,000 yards of trench at once for the attack of an old fortress. This is equivalent to an infantry force of $\frac{3000}{2} \times 4 = 6{,}000$ men.

The Austrian text book on the subject, by Captain Brunner, which may be taken as giving approximately the opinion of the Engineers of Continental Europe, lays down the same numbers of men, as regards these two items, for the attack of one of the detached forts forming the outer line of a great modern fortress. It assumes that three of these forts must be attacked simultaneously in ordinary cases, and that the same working parties would, after the capture of the detached forts, be required to carry on the siege against the *enceinte*. Thus, 18,000 infantry are considered to be necessary for working parties in the siege of a great modern fortress, in addition to the guard of the trenches.

Sir John Burgoyne, in his very valuable article on the attack of fortresses, in the *Aide Memoire to the Military Sciences*, although he deprecates "the attempt to lay down a scale for the number of troops required for a siege in proportion to the size of the place, or the strength of its garrison," on account of the many varying contingencies which must always influence the decision, yet gives an assumption considerably less than the above, and doubtless more nearly corresponding with his Peninsula experiences, viz., that the working party and guard of the trenches should be of equal strength, and, conjointly, should be three-fourths of the garrison, the former being relieved every eight hours, the latter every 24 hours; and he shows that if the total strength of the besieging army, including all arms, be only eight times the number of infantry constantly in the trenches on the above assumption, or $8 \times \frac{3}{4} = 6$ times the garrison, the service will be very hard on account of the large proportion of men that do no duty in the trenches, such as cavalry, bands, orderlies, servants, men in charge of horses, and sick, &c.

Sir John Jones in his estimate makes a certain allowance on account of the men not doing duty in the trenches, whom he specifies as being required for "regimental and camp duties, piquets, and escorts with stores and provisions, &c.;" for the sake of calculation he states them at one-tenth of the whole army, at four reliefs, or four-tenths of the whole army. In his actual calculation, however, he only makes an addition of four-tenths of the men required for guard of the trenches and working parties, *not* four-tenths of the *whole army*. This apparent slip has been corrected in our text books, and the full addition seemingly intended by Sir John Jones has been made. Now this statement, that in a well organised army four-tenths, or nearly one half of the men, are not available for the duty on which they are engaged, is somewhat startling; it is to be accounted for, however, in this way. First, the infantry of an army organised in the normal manner is about eight-tenths of the whole force; and, secondly, it is the experience of all practical soldiers that an infantry battalion numbering 1,000 rank and file, will rarely be able to put more than eight-tenths, or 800 men on parade, owing to the unavoidable deductions which must be made to provide for barrack or camp guards, cooks, orderlies, employed men of all sorts, sick, and defaulters.

A deduction of two-tenths on each of these two accounts, or of four-tenths of the whole army, must therefore be made from a force organised in the normal way, in order to arrive at the actual number of infantry soldiers available for duty in the trenches. A besieging army should not, however, be organised in the normal way, because the cavalry and field artillery cannot be employed in the siege proper, and the larger the proportion of infantry, compared with the other arms in the besieging force, the larger evidently will be the fraction of the whole army available for duty in the trenches. This, then, will indicate one direction in which a change appears desirable in the mode of estimating the strength of besieging armies. *The composition of the force should be suited to the work to be done.*

But one very large and important item is entirely omitted from the calculations made by Sir John Jones and Sir John Burgoyne, and from those given in our text books, although it is acknowledged to be essential, that is, the troops required for the investment. Probably the very inadequate resources at the command of the Duke of Wellington, which obliged him to seek success by irregular methods of attack, where genius and valour supplied, as far as they might, the place of numbers and engineering skill, and which rarely allowed him to attempt a regular investment as a part of a siege, led his two great engineers, whose opinions we so justly venerate, to omit the investing force from their estimates.

In considering the subject scientifically, however, we must not follow their example blindly, but endeavour to arrive at the principles which ought to *ensure* success in a siege, while, at the same time, we must always be prepared to follow in their footsteps as nearly as we can, should the necessities of war oblige us, like them, to make the best use of inadequate means.

A scientific siege ought always to commence with an investment, and this investment ought to be maintained throughout the siege. The number and the proportion of the different arms in this force should, therefore, form the first item in the calculation of the requisite strength of the besieging army.

In countries where cavalry can be employed with success, a preliminary investment by troops of this arm, in combination with horse artillery and engineers, is desirable, the objects being to surprise the garrison, and prevent the introduction of supplies into the place, and by cutting telegraph wires, making bridges, and similar means, to cut off the fortress from communication with the outer world. Reconnaissances of the fortress and its environs are also made to obtain information as to the defences and armament, and garrison of the fortress, and with reference to the line of investment, the camping grounds, or cantonments for the troops, and the most advantageous points for attack. Such a preliminary investment may not, however, be possible in all cases, and although it may materially aid the attack, it is not so essential as the regular investment, to the consideration of which we will therefore pass on.

Captain Brunner states that the average number of men required for the investment of a fortress will be three times the garrison; but the number will evidently depend, first, on the extent of the line of investment, which again depends on the size of the fortress, and on the features of the ground; secondly, upon the strength of the garrison, or the force to be invested, and on the character and composition of this force compared with those of the investing army.

Leaving out of the question maritime fortresses, part of the investment of which would be undertaken by the fleet; omitting also any consideration of a covering army, the necessity for which, as well as its strength and disposition, would depend entirely on the troops which the enemy may have in the field; we will first take the case of an inland fortress, which must be entirely surrounded.

Supposing the armament of the fortress to be of heavy rifled guns, and the surrounding country to be open and well commanded, the experience of the war of 1870-71 has decided that the main line of the investment cannot be traced nearer than about two-and-a-half miles from the works of the defence, and the out-post line from one mile to one-and-a-half miles from the works. Hence, for the complete investment of the smallest fortress, a line about 15 miles long must be guarded, while for the investment of a great fortress, like Metz, with a diameter of over four miles, the circumference of the main line of investment must be nearly 30 miles. The length of the out-post lines in these two cases, however, would be about eight miles and twenty miles respectively.

Now, supposing the small fortress to have a garrison of 5,000 men, not more than 4,000 of these would be infantry, and of them not more than 3,000 would be available for a sortie. Hence, it would probably suffice if the investing force had four battalions in the out-post line (at one battalion to two miles), four more battalions in support in the main position, and four off duty in reserve—in all twelve battalions (or two English divisions without their rifle battalions). This infantry force would have the usual proportion of the other arms, viz., six batteries of artillery, eight squadrons of cavalry, and two companies of engineers.*; altogether about three times the garrison invested, as recommended by Captain Brunner.

* It would be of great advantage if the force of engineers were doubled.

A sortie could not be undertaken by a greater force than about three battalions, a squadron, and a battery. The out-post line, wherever it might be attacked, ought to delay the advance sufficiently to allow of a nearly equal force of infantry, with superior numbers of guns and cavalry, being assembled in the main position to resist their further progress. Should they even succeed in penetrating the investing line at any point, superior forces would rapidly be brought up on both flanks, and their retreat would be cut off.

For a great fortress containing a garrison of say 40,000 men (the probable German garrison of Metz) the investing line must evidently be stronger throughout (although, as will appear afterwards, its total strength will bear a smaller proportion to that of the garrison), because a sortie in force becomes a battle of armies, in which a decided success gained by the garrison might lead to serious results. The out-post line must be considerably increased in strength, in order to be able to resist sufficiently long to allow of the assembly of the requisite number of troops in the main position. Allowing then, in this case, one battalion per mile in the out-post line, we should have 20 battalions always on out-post duty, 20 more would be in first reserve in the main position, where shelter from the weather would be provided for them as early as possible, and 40 battalions in second reserve cantonned in rear of the main position. This would give about 80,000 infantry to defend a position 30 miles long, or about 2,700 infantry per mile. The force by which they could be attacked would not exceed three-fourths of the infantry of the garrison, or about 24,000. The least front on which such a force could attack would be three miles, in which they could deploy about one-fourth in the shooting line, the remainder being in support and reserve; opposed to them would be an equal number of the investors in the shooting line (although with weak reserves in immediate support), and at least 40 guns.

The attack must be purely frontal, and always must itself be outflanked by the concave position of the investors. In field artillery and cavalry the garrison must always be weaker than the investing army.

By persistent efforts and with heavy losses the sortie may, possibly, force back the portion of the investing line attacked, and may even break through; but the time required to accomplish this will be so long that the investing army may bring up infantry and artillery from both flanks, replacing them temporarily by cavalry, and the portion of the garrison which has broken through will find itself surrounded, and cut off from retreat by superior forces of all arms.

In this case then, if the infantry of the investing army be numerically twice as strong as that of the garrison, and if it have its full complement of artillery and cavalry, the investment will probably be efficient—undoubtedly an infantry force of two-and-a-half times the garrison would be ample.

A third case, that of an army taking refuge in a great fortress, and being invested there, as the French were at Metz, need not here be considered. In such a case, a siege proper is almost impossible, and the result may be most certainly attained by a simple investment, provided that the investing army is sufficiently strong to prevent a portion of the invested force from breaking out.

We may assume then, that for the complete investment of a small fortress, the infantry force must be three times that of the garrison, and that in the case of a large fortress, the proportion may be reduced to as low as twice the garrison, because, in the latter case, the total number has increased in a larger ratio than the periphery of the circle over which they are distributed. In all ordinary cases the investing infantry must be fully supported by artillery and cavalry.

It must be noted, however, that two variable factors in the calculation must never be lost sight of, viz., the character of the troops on both sides, and the configuration of the country. Thus, at Belfort in 1870-71, a German Army of 17,602 infantry (18 battalions of landwehr), with 30 field guns, a regiment of cavalry, and a company of pioneers, fully invested the French garrison, about 16,000 strong, of whom, however, only two-and-a-half battalions of infantry, two-and-a-half companies of garrison artillery, and one-and-a-half companies of engineers were regulars, the remainder being mobiles imperfectly disciplined, without cavalry or field artillery. The siege was prosecuted with the addition of only four siege artillery divisions, and four siege pioneer companies to the investing army.

Again at Strasburg in the same war, the French garrison mustered 11,000 infantry, with 4,000 national guards, and 770 cavalry, but without field artillery. The investing force was 10,000 infantry, with 1,800 cavalry, and 54 field guns, and they were able to cope with the garrison, not only on account of superior organisation and the presence of the auxiliary arms, but chiefly because the Rhine, the Ill, and the inundations so shut in the garrison of the fortress, that practically it was only necessary to invest the western side, where the out-post line of the investment was only about three miles long, and the main line about five miles.

Let us now consider what additional troops are required for the prosecution of the siege. Clearly, cavalry and field artillery will be useless—the siege troops must consist of infantry, engineers, and garrison artillery. Of these the infantry are needed to make the siege works with the aid of the engineers, and to guard them from sorties, and finally it may be to overpower the garrison in an assault when the way has been prepared for them. For the first of these duties, it is generally agreed that a working party of about 1,500 men in four reliefs, or 6,000 infantry, are required for the attack of each detached fort, that three of these forts must usually be attacked simultaneously, and that the same working parties will be needed to combine their labours in the further attack of the *enceinte* of a great modern fortress, giving a total of 18,000 infantry.

To guard the trenches it is usually considered that an infantry force of three-fourths the infantry of the garrison, with three reliefs or a total of nine-fourths the infantry of the garrison is required. But we have already, in the investing force, a guard which is sufficient, as long as the distance from the fortress is considerable, and no advance is being made; to push on closer to the fortress, however, more troops must be employed, and they must be more frequently relieved. Moreover, while for the investment two reliefs are considered enough, three are required for the guard of the siege trenches, their duties being more arduous. Supposing the detached forts of a great fortress to be about a mile or 2,000 yards apart, and that three are attacked, the extent of the line attacked will be about three-and-a-half miles, and that of the first trenches about four miles, supported on each flank by about two-and-a-half miles of investing line pushed forward in echellon. The troops of about one-fourth of the whole investing line will therefore become available for the guard of the trenches, and it probably would suffice if the infantry were doubled in strength in this part of the line, which, with three reliefs, would give always about 3,000 men to the mile on duty in the trenches, in addition to the working parties.

In a small fortress about one-third of the investing line would be included in the attack, and this portion of the troops of the investment would take part in guarding the siege trenches, and if doubled in strength the result would be about the same as above.

In any case this portion of the investing troops must be deducted from the total number considered necessary for the guard of the trenches, and which will vary according to the character of the troops composing the garrison, and the activity of the defence.

On the foregoing data, the theoretical calculations of the necessary strength of besieging armies, as regards their infantry, may be made somewhat as follows:—

To besiege a small fortress with a garrison of 5,000 infantry:—

For the investment,	5,000 × 3	= 15,000.
For the working parties,	1,500 at 4 reliefs	= 6,000.
For the guard of the trenches (additional to the 15,000 for the investment)	$\frac{15000}{3}$	= 5,000.
		26,000.
Add for camp duties, say $\frac{2}{10}$ of this number		5,200.
Total Infantry (about six times the garrison)		31,200.

In addition to about this number of infantry, there would be required the auxiliary arms for the investing corps, viz.

Field artillery	From 6 to 8 batteries.
Cavalry	„ 6 to 8 squadrons.
Engineers	„ 2 to 4 companies.

And for the siege proper—

Garrison artillery, in the proportion of 30 men per gun, or heavy howitzer, or mortar which may be required, say	20 batteries.
Engineers, about	8 companies.

To besiege a large fortress, surrounded by detached forts, and garrisoned by 40,000 infantry:—

For the investment, 40,000 × 2	80,000
Working parties, 3 times 1,500 at 4 reliefs ...	18,000
Guard of the trenches, $\frac{80000}{4}$ in addition to the investing troops	20,000
	118,000
Add for camp duties as above	23,600
Total Infantry (about three-and-a-half times the garrison)	141,600

Add for the investment—

Field artillery	40 batteries.
Cavalry	40 squadrons.
Engineers	10 to 20 companies.

Add for the siege—

Garrison artillery (as above) say ... ... 60 batteries.
Engineers ... ... 24 companies.

The only examples of regular sieges which occurred during the war of 1870-71, were those of Belfort and Strasburg before alluded to. The former was undertaken with such inadequate means, that it cannot be used as a basis for calculation, particularly as it was not successful; but the siege of Strasburg was pushed with great vigour, and affords a sufficiently good example with which to compare the mode of calculation proposed.

The numbers employed by the Germans were as follows :—

	Infantry.	Field Artillery.	Cavalry.	Engineers.	Garrison Artillery.
		Batteries.	Squadrons.	Companies.	Batteries.
For the investment	10,000	9	12		
For the siege (additional) ...	37,500	10	12½		36
Total	47,500 = 47½ battalions.	19	24½	15	36

By the mode of calculation proposed, the number of infantry required for this siege would have been :—

For the investment—

Out-posts at 1 battalion per mile for 3 miles	3,000	12,000
Reserve in main position, ...	3,000	
Relief of the above, or 2nd reserve	6,000	

Add for the siege—

Guard of the trenches (the siege works being co-extensive with the investment line) 12,000

Add for working parties (the attack being on a great *enceinte* considered equal to 3 forts) 18,000

42,000

Camp duties at two-tenths 8,400

Total 50,400

The proposed proportions of the other arms would have been for the investment—

Field artillery ... ... 6 batteries.
Cavalry ... ... 8 squadrons.
Engineers ... ... 4 companies.

manding points, the distance between any two of them in open country, being limited only by the effective range of their artillery fire against troops, the ground between being commanded from either one or the other. Generally, indeed, but not invariably, the fire of two forts would cross in front of an intermediate one, but this would be at a very long range.

Thus, in modern fortresses, the defence derived from the works is, for the greater part of the perimeter, confined to that afforded by the artillery fire of the forts. Near the forts the fire of small arms comes into play, and the forts themselves form a material obstacle for a short distance. The place may thus be looked upon as one surrounded by an enciente of varying strength and character.

Now it is evident that, however powerful the artillery fire of the forts may be, it would be impossible to trust to it entirely for closing the intervals between them. If it were the only obstacle—even supposing it to be so well arranged that it could not be silenced—yet darkness or fog would render it ineffective, and it could not, with certainty, prevent the enemy pushing his trenches between the forts, and thus passing the line of defence.

But darkness or fog would not prevent the guns acting if the position of the enemy were known, and this would be discovered by proper guards and piquets; and the trenches could not be carried between the forts if guns could be placed to enfilade them, or sorties made to destroy them. It is thus seen that even with powerful forts, the line of defence must be completed by a body of troops, in at least sufficient numbers to be capable of guarding the intervals between them, and provided with field or position artillery; and these troops must be independent of the garrisons of the forts, as they are required to be in use simultaneously. A Garrison Force and a Field Force are thus necessary.

Now, if this is the case with strong works uninjured by the enemy's fire, which is the state of things assumed above, much more is the Field Force necessary when the flanking fire is weak, or is liable to be reduced or silenced by the enemy. For then it might be possible for him, if he had an adequate object to gain, such as the destruction of a dockyard or of large quantities of stores, to march a body of troops boldly past the works, accepting such loss as they could inflict, and in the absence of any continuous material obstacle he could only be checked in the movement by a Field Force, capable, with such assistance as the works could give, of closing the interval through which he might attempt to penetrate.

If the vital part of the fortress were guarded by an interior continuous line of fortification, and this line were so near to the outer works that the whole of the space between could be swept by artillery fire, no open movement could be advantageously made by the enemy to pass between the forts without taking them, as, supposing him successful in that part of his operation, he would still be in front and under the fire of an uninjured work, which it would require a regular attack to reduce; and, to carry on such an attack, a constant supply of stores would be necessary, which could not be brought up unless the forts were completely silenced.

If there were an interior line, but it were too far from the outer forts for its fire to command the whole of the interval, the enemy might try to introduce a small body of men with field guns, in order to attack one of the forts by the gorge, where they would probably be weakest.

In the attack of any fortress a few men might try occasional raids within the lines in the hope of doing some mischief.

Reconnoitring parties would also certainly pass in if they could, and attempts might be made to take a fort by surprise.

Besides furnishing regular guards and piquets, the Field Force would supply men for the various batteries, &c., which it is necessary to make and occupy in nearly every fortress, when placed in a state of defence, their construction being for financial reasons left for the time of war.

This is a service which it may be fairly expected to perform, as if these additional fortifications strengthen the place they diminish the work the Field Force may have to do.

We may now consider the manner in which the troops should be divided between—

1. The Garrisons of the forts.
2. The Field Force.

The numbers of the first must of course be calculated according to the extent and armaments of the works, allowing enough men to work the largest number of guns that it is likely will be required at once; guards for the flanks, entrances, &c.; orderlies, cooks, cooks' mates, &c.; and a reserve, which may be taken as equal in number to the men on duty. The reserve would of course be available on an emergency, such as an assault.

The strength of the Field Force depends, in the first place, on the guards and piquets which it may have to furnish. The number of these can be calculated for any particular place, supposing them to be laid out in the manner prescribed by regulation, and the distribution should be so arranged as to allow the men a day off to a day on duty.

In the second place, it depends on the force necessary to prevent the enemy passing between the forts, supposing them partly silenced; the strength, character, and objects of the force attempting this depending principally on the style of the interior defences. As siege operations would probably be carried on against two adjacent fronts, it might be assumed that both these would be assaulted. The Field Force should therefore be capable of holding any two adjacent fronts of the fortress, in such strength as to prevent, or check any probable attack in the open, and to do this with only slight assistance from the forts.

It may be found that the piquets and supports of the front attacked will be sufficient to do this. If they are not, the requisite number must be added to the garrison, and in any case it will be necessary to add some troops to those calculated for patrols, in order to perform various miscellaneous duties about the fortress, such as guards over stores and magazines, escorts, and orderlies, and to form a small reserve immediately under the orders of the Commandant of the place, ready to act on any emergency.

A garrison is also required for the central work of the fortress, if there be any.

To illustrate the previous remarks, let us take an imaginary fortress, and calculate the garrison required for it.

Suppose the fortress to be on level ground, and to consist of a ring of outlying forts without any central *enceinte*; the forts to be nine (9) in number, 5,000 yards apart, at a distance of 7,160 yards from the centre of the town.

I.—*Garrison of the Forts.*

Assuming that 15 guns can be used in each fort at once, and that there are five flanks and two entrances to guard, we may make the following calculation:—

Men to work 15 guns, at 7 men per gun	105 men.
Guards for five flanks and two entrances, at four men each	28 „
On duty in magazines, cooks, orderlies, &c., say ...	17 „
	150 „

Doubling the number for reliefs we have:—

Garrison of one fort	300 men.
Total garrison of nine outlying forts	2,700 „

II.—*Field Force.*

Supposing the piquets to consist of 25 men, at intervals of 300 yards, having double sentries detached to the front, then 18 piquets will be required between each pair of forts, amounting to 450 men. If these are supported by four main guards, of 300 men each, amounting to 1,200 men, we have a total of 1,650 men for the interval between each pair of forts. This gives a total of 14,850 men for piquets and guards.

In actual practice the calculation would be much more complicated, as the same number of men is not likely to be required on each front; but a perfectly symmetrical fortress, such as the one assumed, is equally liable to attack on all sides, and therefore must everywhere be equally guarded.

It does not follow that for a fortress of equal size, but on uneven ground, a smaller number would suffice; in most cases the piquets would have to be disposed on a longer line than that joining the forts, either by being advanced to the front, or by being placed irregularly, either of which arrangements would require more men than that assumed. On the other hand the sentries might be posted at larger intervals, unless the country were very unfavourable to the detection of the movements of hostile troops.

Besides furnishing piquets, the Field Force has also to supply a sufficient number of troops to be capable of resisting any attempt of the enemy to penetrate between the forts; this number must now be calculated in order to see what addition, if any, is necessary to its strength.

For the purposes of calculation some assumptions must be made as to the position to be occupied, and as to the strength of the force that would be required for it.

In the first place we may assume that the forts being 5,000 yards apart in an open country, it will be only necessary to hold 3,000 yards out of that distance strongly, the cross fire of musketry from the forts and from the flanks of the line, with the aid, if necessary, of the troops in reserve, being sufficient to close the gaps. Secondly, that an allowance of three men to the yard will give a sufficiently strong force for the purpose. It might be posted in a first line of skirmishers, supports, and reserve, with a general reserve of one-third of the whole.

Thus to occupy 3,000 yards in each of two fronts, at three men to the yard, we require :—

$$2 \times 3{,}000 \times 3 = 18{,}000 \text{ men.}$$

To supply this number we have, say :—

Outlying piquets of two fronts	900 men.
Main guards of two fronts	2,400 ,,
Half main guards of adjacent fronts	1,200 ,,
Total at hand	4,500 ,,
No. required	18,000 ,,
No. to be provided	13,500 ,,

This addition would include the general reserve to be held at the immediate disposal of the officer commanding. Men are still required for miscellaneous duties; their number may be taken at 500.

We have thus arrived at the following totals :—

Garrisons of outlying forts		2,700 men.
Field Force	Piquets and main guards	14,850 ,,
	Reserve	13,500 ,,
	Miscellaneous	500 ,,
Total garrison		31,550 ,,

This is an average allowance of 70 men to every 100 yards of circumference of the fortress.

Again, suppose in the same fortress that a central work were constructed, with a radius of 1,400 yards, and a circumference of about 9,000 yards, so that the distance from it to the outlying forts would be about 5,700 yards; then the whole of the ground within the forts would be under artillery fire, and the centre of the position would be secure.

Under these circumstances it would be useless for the enemy to attempt to introduce any large body of men within the outer line; it would not, therefore, be necessary to hold in strength the intervals in it. Small parties might, however, try to enter, in order to reconnoitre, or to do what harm they could; the pickets are therefore still essential. A garrison is also required for the central work, and of course a small reserve under the immediate orders of the Commandant of the place.

The calculation of the force required in this case would therefore stand as follows :—

Garrisons of outlying forts		2,700 men.
Field Force	Guards and piquets	14,850 ,,
	Reserve, say	1,000 ,,
	Miscellaneous	500 ,,
Garrison of central work, say		1,000 ,,
		20,050 ,,

This is an average allowance of 44 men to every 100 yards in circumference of the fortress.

There are some particular cases which may now be noticed; not going into detailed calculations of the number of men required for them, but indicating the principle on which these calculations should be based.

1. A fortress, consisting of a double ring of detached forts.

This may be treated as a fortress with a central work, as the enemy could not venture to pass through the intervals of the inner line, the forts of which would be uninjured. In calculating the garrisons of the inner forts, the numbers arrived at need not be doubled for reliefs, unless they are so few as only to suffice for the necessary guards.

2. A fortress of such an extent that the whole area between the central work and the outlying forts is not under fire.

The enemy might here endeavour to reduce the length of the siege, after he had to a certain extent silenced the forts, by carrying one of them by the gorge. It would depend on local circumstances whether he could be best met between the forts or behind them, or whether the construction of a work within the outer line would not check any such attempt with a less number of men than would be required to meet it with a Field Force.

3. A fortress partly surrounded by water.

The coast would have to be carefully watched; but it would depend on the character of the landing-places whether any large Field Force would be wanted for that part of the defences. A few mounted batteries of artillery, with positions prepared for the guns, would be most probably necessary to secure it.

In the foregoing pages it has been attempted to indicate in what manner the garrison of a fortress should be calculated, supposing that there is no difficulty in obtaining the necessary troops. But it is extremely possible that a general might find himself called on to defend a fortress which would require, theoretically, a larger number of men than he could spare for the service. An enquiry into the measures that should be adopted under these circumstances will therefore be useful.

In the first place, it may be observed that a large Field Force is not likely to be required for purely defensive purposes at the commencement of the siege. If the forts are in good order they should be sufficient to prevent any thought of the enemy passing them in force until he has reduced their fire; there will, therefore, be a certain breathing time in which to prepare additional aids for the defence.

The arrangements in the forts for lateral and reverse fire should be examined, and the guns secured from the attack by traverses or blindages, and additional emplacements might, if necessary, be constructed in the forts, or in works thrown up in rear of them.

As this would have to be done under fire, it would, for the most part, have to be executed by military labour, but any assistance from civilians that could be obtained should be used. For instance, timber for blindages, gun platforms, &c., should be prepared by civilians and brought to the front ready for use. If the fortress does not already include a central work, one should be immediately constructed on a field trace; this will strengthen the defence in most cases almost more than anything else, and the work could be entirely done by civilian labour with a small amount of military superintendence.

In order to lessen the number of men required for piquets, obstructions should be prepared which would check the enemy's advance, and cause him to reveal his position. These would, of course, be of the usual character—such as abattis, entanglements, &c.

It should be borne in mind that the defender should so arrange his obstructions as not to interfere with his power of making sorties, as they form a mode of defence of which even the weakest garrison should not voluntarily deprive itself.

The forts should, if possible, be provided with lime or electric lights for the purpose of illuminating the surrounding country.

All transport and commissariat work, all fatigues in barracks, everything that possibly can, should be done by civilians, so that the troops may be fresh for fighting when called on.

Shelter trenches and gun emplacements should be made between the forts, so that the intervals may be more easily held, although, in some cases, a small force might find it expedient not to take up a position between two forts in case of an attack, but to throw back one flank, resting the other on a fort as a pivot. This position would have several advantages over the other; besides being more secure from fire from the enemy's siege batteries, the attacking force would be drawn into an awkward position, exposed to reverse as well as flanking fire from the forts, and to fire from the untouched central work, if one has been constructed, and, moreover, great opportunities would be given for flanking movements. As soon, therefore, as the attack has developed itself, positions for the Field Force might be prepared on either side of the threatened faces. A disadvantage of this mode of defence is, that it temporarily surrenders to the enemy part of the ground within the forts, which it should be one of the objects of the Field Force to protect; but, of course, with a small garrison sacrifices must be made for the safety of the fortress. With the aid of every device it may yet be impossible to arrange the troops in the manner proposed for a complete garrison; in this case, everything else must give way to the absolute necessity of providing the garrisons of the works, and a reserve force to move where wanted. To illustrate this, let us assume that the fortress, for which a force of 20,050 men has been calculated as the right one, is to be defended by 10,000 men, and let us consider what is the best arrangement for them

In the first place, the reserves for the garrisons of the forts might be diminished by one-half, and to the central work might be allotted 750 men instead of 1,000.

Thus, we get—

Garrisons of forts	225×9	=	2,025
" central work		=	750
			2,775

This leaves 7,225 men to be disposed of.

Piquets cannot be laid out as formerly proposed, as there are not enough men; but if special attention were given to the roads and other likely ways of approach, if patrols were frequent and obstructions judiciously placed, a considerable degree of security against surprise might be attained and reconnoitring checked. Supposing that there were a dozen piquets between each fort, each consisting of twenty men, then they would be about 400 yards apart, and might throw out double sentries to the front and flanks, who would be near enough to one another to observe the ground properly in most cases. This distribution would require $9 \times 12 \times 20 = 2{,}160$ men, and with a main guard of 300 men to each front, or 2,700 in all, we get a total of 4,860 men for guards and piquets.

There are still 2,365 men to dispose of: they may be allotted—2,000 to the reserve, and 365 to miscellaneous duties. The reserve is made stronger than before, as it is likely that it will have more calls made on it.

The troops will, therefore, be distributed in the following manner:—

Garrison of forts		2,025
Field Force	Guards and piquets	4,860
	Reserve	2,000
	Miscellaneous	365
Garrison of central work		750
		10,000 men.

The number of men that could be brought up to defend two adjacent fronts would be—

Outlying piquets, two fronts	480
Grand guards, ,,	600
Half of adjacent grand guards	300
Reserve	2,000
	3,380 men.

As the fortress is assumed to have a central work, it would not be liable to an attempt of the enemy to penetrate between the forts in force; but owing to the smallness of the piquets and grand guards, it would be open to annoying incursions of small parties, if any of the works were partially silenced, so that the defenders would not be able thoroughly to utilise the space behind the forts.

If there were no central work, or if one existed, but too far from the advanced works to support them by its fire, the difficulties of defence with a small garrison would be much increased. It would become so very necessary to have as large a force as possible in hand to meet any move of the enemy, that efficient piqueting might not be practicable. In such a case it would be advisable to give up piquets, except at particular points, such as roads, and the following plan might be adopted. The garrisons of the forts might be increased by from 50 to 100 men each, whose duty would be to patrol the ground about them at night; by these means the advance of any considerable body of men would probably be detected.

The country should be cleared of everything serviceable to the defenders, or likely to be useful to the attacking forces if they got possession of it. The bulk of the garrison should be concentrated in some central spot, from which it could move easily on any threatened point.

The distribution of a garrison of 10,000 men, with the same exposed perimeter as before, and with a central work too far from the forts to support them with its fire, would thus be somewhat as follows:—

Garrisons of forts	2,700
Extra men in forts for patrols	900
Garrison of central work	750
Field Force	5,250
Miscellaneous	400
	10,000 men.

The distribution of a small garrison is not so easily reducible to rule as that of a large one. A capable commanding officer will find many ways of economising troops, so as to be able to strengthen the vital points when necessary.

It will, no doubt, be noticed that in the foregoing pages no calculation of numbers is based on the requirements for making sorties or constructing counter approaches. The reason of this is, that it was desired to ascertain the minimum garrisons necessary for defence, which these requirements do not afford absolute data for determining. It is evident though that the Field Force would be available for these purposes, and should be used for them. Sorties have always been recognised as an important portion of the means of defence, and counter approaches are likely to play a great part in any future sieges.

A few remarks, in conclusion, on the composition of a garrison may be useful.

Out of the estimated number of 300 men for a fort of the imaginary fortress, 210 should in strictness be artillery, and the remainder infantry, with a few engineers; but it would be seldom possible to maintain this proportion, which would require 1890 artillerymen for the forts alone, without including those in the central work, or in the Field Force; and the guns would, therefore, have to be chiefly manned by infantry,—about three artillerymen might be allowed per gun. In calculating the garrison of an actual fort the nature of the guns, the manner in which they are mounted, and the magazine arrangements must be noted, and the number of men per gun, with the proportion of artillerymen, decided upon accordingly. The garrison of the central work would be composed similarly to that of the forts.

The Field Force would be principally composed of infantry. It would, however, require some artillery to man any guns that might be put in position between the forts; and it should also be provided with two or three mounted batteries, so that there might be a few guns to post as the varying circumstances of an action might require. Of course the same proportion of artillery would not be required for defensive purposes as for a force acting independently, since some assistance would be given by the forts.

A small body of cavalry would be found of immense service, and should, if possible, be extemporised if there be none in the place. It could assist the patrols and convey information, and, in the case of an attack, could be moved rapidly to the threatened point, when it would be sure to find an opportunity of acting with effect.

Engineers would, of course, be necessary; they can be assigned to no fixed point, but would be moved about from place to place as they might be wanted, and as they, like the artillery, would be almost certainly few in numbers, their duties would be principally confined to superintending working parties of infantry and civilians.

These proportions of the various arms would be necessary for a defence, during which it was not proposed to make powerful sorties. A force to be thoroughly efficient for the latter purpose should be provided with more field artillery and cavalry, as it might have to act independently of the forts, and to rely for a time on its own resources.

J. F. LEWIS,
LIEUT., R.E.

PAPER VII.

NOTES ON THE ERECTION OF THE

TARLEE BRIDGE,

IN THE SALTARA COLLECTORATE OF THE

BOMBAY PRESIDENCY.

By Lieut. E. C. Hart, R. E.

The military trunk road from Poona to Belgoon, Dharwar, and thence to Madras, crosses the Tarlee river close to its confluence with the Krishna, which at this point runs nearly parallel with the road. Owing to the muddy state of the banks in wet weather great obstruction was caused to traffic, consequently, about the year 1860 a bridge consisting of three spans, each of 40 feet, was built, resting on brick walls with wooden curbs. As was afterwards discovered, the waterway was altogether too small, and consequently the scour in the bed of the river was very great, and the bridge had not been in existence above about four years when one of the piers was undermined, and the entire bridge became a ruin. In December, 1874, it was determined to rebuild the bridge, giving it four spans each of 40 feet, the foundations to be taken down to hard rock, and built entirely of coursed trap stone and lime masonry; moreover, the springing of the bridge was raised to 43 feet above the top of the foundations, so that the roadway might be just above the highest flood on record. The rise of the arch was designed as 8 feet, and the arch ring as $2\frac{1}{4}$ feet thick, the piers being six feet thick at top, and nine feet at bottom of superstructure. The foundations were designed as rectangular blocks averaging about 21 feet in depth, in three equal steps of seven feet each, each step having a 6-inch offset on all four sides, so that the bottom of the foundation of the pier was a rectangle measuring 42 feet by 12 feet. In the fine weather—that is, from 1st November to 1st June—the water in the river, with the exception of occasional small floods, would be but ankle-deep, but during the remainder of the year the depth of water was liable to vary in 24 hours from 2 to 40 feet; so that for about five months in the year no excavation in the bed of the river was possible. Orders were received to commence work on the 15th December, 1874, and by the 19th the erection of mortar mills, lime kilns, &c., was in progress. It is not here intended to give an account of the actual building work, though some remarks on the stone, cost of materials, &c., may be eventually added, but to describe the method adopted for excavating the foundations, which method we have not seen before suggested.

It will here be as well to mention the nature of the soil, which was loose sand and pebbles to a depth of from 16 to 20 feet, thoroughly permeated with water and containing strong springs; below this was a stiffer soil, in some places clay, in others soft gravel, in others again very hard gravel approaching conglomerate, and below all the rock, consisting of a very nearly horizontal sheet of trap, at a mean depth of 26 feet below lowest water level.

The first operation was to line out the bridge, so that its axis might be in that of the old approaches, and that the abutments and piers might clear the foundations of the old bridge. The first requisite was obtained by erecting masonry pillars topped with flat slabs in the exact centre of the old approaches, and at convenient distances from the river, the slabs being marked with a chisel; and their reduced levels, with reference to that of the proposed springing level of the arches, being registered, gave permanent bench marks, by referring to which the axis of the bridge, or any required levels could at once be determined. Pegs having been ranged from the above bench marks in the bed of the river by means of a theodolite, the site of the centre pier of the bridge was selected, in the exact centre of the middle span of the old bridge, and a line at right angles to the bridge axis from this point gave the axis of the middle pier of the new bridge. Bench marks, in the shape of pillars capped with slabs, were erected in this line about 70 feet up and down stream side of bridge axis. The slabs were chisel-scored with lines at right angles to each other, one being in the axis of the pier. Bench marks for the remaining two piers' axes and the faces of the two abutments were built in the lines at right angles to the pier axis already found; the slab stone caps were all built exactly on the same level, and the lines parallel to the bridge axis ranged with the theodolite, and scored thereon. The slabs had been laid at approximately the proper distances from each other as accurately as could be done with a tape; to get the *true* distances a wire was strained to 20 lbs. by a Salter's spring balance, and the distance accurately measured thereon; the distance was then measured off with the same strain along the two parallel lines, thus giving the axis of the other piers and abutments, so that any line joining a pair of bench marks gave the axis of the pier or face of the abutment in question. All the right angles were then checked with the theodolite and found absolutely correct. Finally, the levels of the bench marks in the river bed were registered with reference to those of the approaches, and formed new points of reference; thus the second requisite, that of avoiding the old foundations as much as possible, was secured. The next thing to be done was to divert the water in the river. It was decided to commence operations on the south abutment, on which side of the river were the stores, kilns, &c. The bed of the river, therefore, as near as possible to the north bank was deepened, and the sand, &c., thrown out and made into an embankment about three or four feet high. This left the south half of the river bed dry.

The plant available was as follows:—

One double cylinder,		12-H.P.	portable engine,	new
One single	,,	10-H.P.	,,	old
One single	,,	6-H.P.	,,	old

Two 8″ Gwyne's centrifugal pumps complete
One 5″ ,, ,, ,,
One 4″ ,, ,, ,,
About 150 R.F. sheet-iron water shoots.
10 or 12 long spars from 40 to 80 feet in length.

It may be as well here to mention the various stores that experience taught us should always be at hand. The principal were:— Thick English leather hide for washers, valves, &c.; thick sheet vulcanised india-rubber for washers; castor oil, sweet oil, English tallow; hemp for packings; washer rings for engine water gauges; red and white lead; resin; single leather driving belts (two for each engine), 6″ or 4″ wide according to size of pump; zinc and brass for castings; files of all descriptions; the usual fitters' tools; leather laces for driving belts; coarse canvas for sand-bags with twine.

Of course picks, hoes, and crowbars were in abundance; a large number of baskets, both iron and cane, were also used, as barrows are not employed in this country.

As the new abutment came in rear of the site of the old one, part of the river back, and the old embankment to the height of 30 feet had to be removed; the latter was easily picked out, but the former was very stiff red clay, on which the natives made but slight impression. Very considerable saving was effected by blasting this out as follows:—A hole 4″ diameter was bored with boring apparatus in the clay to any suitable depth; lines of least resistance of six feet with 8 lbs. country powder gave very good results. The mines were tamped with well-rammed moist clay, and it was found that six men could in four hours bore, tamp, and fire two mines, throwing down a mass of clay, which it would have taken eight to ten picks from two to three days to remove.

The report was almost nil; the mass of earth either fell forward, or was so cracked and shaken as to be easily detached in large masses by means of crowbars; the earth was then removed as usual in baskets, and carried by women and children.

There is nothing worthy of being noted in the excavation of the south abutment, which was all in stiff clay, or very large pebbles, the sides of which stood well.

Pier No. 1 was more troublesome, as not only was the underground flow of water very much greater, necessitating the continual use of the engines and pumps, but the excavation being through sand continually filled up. The rush of water towards the pumps carried sand and stones into the latter, continually choking them; several methods were tried to filter the water, such as straining it through old broken cane baskets, revetting the sides with stakes, behind which dry grass was trampled down, but all to no purpose; in fact the remedies were found to be worse than the evils sought to be cured, for pieces of cane, wisps of grass, &c., *would* find their way into the pump discs and choke the pump, whereas with cages formed of $\frac{1}{4}$-inch round iron, fixed over the foot valves of the pumps, all but the smaller stuff could be prevented from finding an entrance. Over and over again, just as the men were getting on well with the excavation, the water would rise, owing to the pumps being choked, and there was nothing for it but to stop the engines, open out and clean the pumps, and then set to work again to reduce the water, during the whole of which time hundreds of hands would be standing idle. At last, by dint of sheer perseverance, a layer of clay was reached on the south side of the excavation, along which the springs were led, with a very gentle slope towards the pump, so that most of the sand and stones was deposited before reaching the pump well, and was promptly removed. Eventually the rock was reached, levelled off, and by the 31st May, or in five months and ten days, the masonry was raised five feet above the top of the foundations, both in the abutment and one pier.

During the next five months no work could be done, owing to the floods, the level of one of which, occurring on the 9th September, rose two feet above the proposed springing line of the arches, and the whole country was under water for miles, but advantage was taken of the pause by thoroughly repairing the engines and pumps, collecting fuel and other material, and in other ways preparing for a fair start as soon as the monsoon should be over. The masonry work of the abutment and pier was also slowly carried up as opportunity afforded.

Having now a better knowledge of the substrata of the river bed, careful calculations were gone into as to how the work should be carried on during the ensuing working season.

At first sight it would be said that a cofferdam would be not only the most expeditious, but also the most economical arrangement, but the drawbacks were—

1. The great cost of suitable timber, and the difficulty of procuring sufficient quantities and conveying it up country over bad roads.

2. The certainty that the timber could not afterwards be sold or transferred at anything like its original cost.

3. The time that would be required before the excavation proper could be commenced, for driving the piles (there being but one hand pile driver, and that a very old one available), dredging out between the two rows of piles, and filling in with puddle, would have been very great, and would have spun out the work too dangerously near the commencement of the rainy season of 1876.

4. The vast difference between skilled and ordinary labour, carpenters being difficult to get at 8, 10, and 12 annas a day, whereas common labourers can be got—men at $2\frac{1}{2}$ and 3 annas, and women and boys from $1\frac{1}{2}$ to 2 annas.

5. The difficulty of driving piles regularly, the whole river bed to a considerable depth being filled with large blocks of masonry, the debris of the old bridge.

Hence, it was decided that cofferdams should not be employed, but that the excavations should consist of open pits with their sides revetted, as will be described further on; that no attempt should be made to keep the water *out*, but that it should be kept under by means of the steam pumps.

On the 12th November the excavation for the north abutment was commenced, and proved a very troublesome job (the method for revetting the sides will be described when treating of piers, Nos. 2 and 3); rock was not reached until the 11th February, or in three months, and even then some time was spent before the rock could be properly cleaned, levelled, and the first few courses of masonry laid. The principal difficulties in this excavation were—

1. The great strength of the underground springs of water, it being early in the season for excavations under water level.

2. The extreme fineness of the sand composing the substrata; for 19 feet in depth the sand was as fine as that used for drying writing, and, from the force of the water pressure, this fine sand over and over again silted up the excavation.

3. The very cramped position of the site, which was surrounded on three sides by the old embankment towering above it to a height of nearly 30 feet.

The strength of the underground springs having very markedly diminished in February, it was determined to excavate piers, Nos. 2 and 3, in one enclosure, as this was calculated to be more expeditious and economical than if they were taken in hand piecemeal; moreover, one pumping operation would suffice for both, and a greater number of labourers could be employed at one and the same time.

The first operation was to choose a site for the pump-well, free from debris of the old bridge. An iron pricker was driven into the river bed in various spots until one was found fairly free of debris, midway between the two piers, and as near the axis of the bridge as possible; this spot was just at the end of the up stream cut water of the old central pier. Here piles were driven forming a rectangle, 15 feet parallel to bridge axis, and 6 feet at right angles to the same. The piles were about 3 to 4 feet apart, and their tops were connected by waling pieces. The area $15' \times 6'$ would, it was calculated, be sufficient for the four pumps,—two, a large and a small, just above ordinary water level, and two sunk very considerably below that level. It is a known fact that centrifugal pumps work better with a throw than with suction; at the same time, it was necessary to have some means of reducing the water in case the driving pulleys of the lower pumps were at any time submerged.

A somewhat larger area than $15' \times 6'$ would, it is thought, be preferable on another occasion. Subsequently, as the excavation continued, a second set of waling pieces was introduced at the level determined on for the platform for the lower set of pumps, and the piles were cross braced in every direction, care being taken to leave sufficient openings for the driving belts. Next, the area for the intended inclosure was laid out, measuring 114 feet parallel to the bridge axis, and 49 feet both up and down stream sides of the axis. The dimensions were obtained thus :—

Calculating upon getting fairly stiff soil, that is sand and clay mixed, at a depth of 16 feet below the bed of the river—

Extreme length of piers	42 feet.
4-foot berm on either side	8 „
Slopes of $1\frac{1}{2}$ to 1 for a depth of 16 feet	48 „
Total...	98 feet.

or 49 feet up, and the same down stream of bridge axis.

The length was got as follows :—

Distance between axis of piers	46 feet.
Half width at bottom of two piers, each 6 feet ...	12 „
4-foot berm on either side	8 „
Slopes of $1\frac{1}{2}$ to 1 for a depth of 16 feet	48 „
Total...	114 feet.

This being laid out correctly, rough round babool wood stakes (costing 9 rupees per 2,400 lbs. weight), from 4 to 6 inches diameter and 6 to 7 feet in length, were driven till their heads were on a level with the ground, at about 5 feet equal intervals, all round the enclosure; mango planks (costing 1 rupee per cubic foot ready cut), 1 inch thick, were laid behind the stakes, the sand being excavated to admit of the planks being got into position; the soil inside the enclosure thus formed was then excavated nearly to the bottom of the planks; a second row of stakes driven, breaking joint with the first row, that is the stakes came $2\frac{1}{2}$ feet in a longitudinal direction from those on each side of them in the first row; a second row of planks was then laid, their tops being an inch or so above the bottoms of the first row, and so on until hard soil was reached. Of course, all the planks in each row were as nearly as possible one width, though one set might be 15 inches wide and the next only 9 or 10 inches.

Thus, the revetment assumed the appearance of a series of steep steps, which, it was found from experience, would stand perfectly well at a slope of 1 to 1; this inclination was accordingly given them, though space had been allowed for slopes of $1\frac{1}{2}$ to 1, hence a larger berm was obtained at the bottom—a very necessary precaution owing to faults in the hard gravel layer overlying the rock, which in some places had been scoured to a greater depth than at others. The steps provided easy access to the pits, served for the basket men to stand on, and broke the force of the water, which, falling in small cascades, was unable to disturb the sand and pebbles. The slope of the steps being 1 to 1, of course their treads were equal to their rise; each step was filled up flush with sand excavated from the pit, but no attempt was made to keep the water out altogether, as that was found hopeless, and only to add to its energy in some weak point. When the hard gravel layer was reached, and the bottoms of the last row of planks firmly bedded therein, the true size of the base of the pier was marked out, and a wall of sand-bags, filled with clay, and their joints well stopped with stiff clay, was built from 1 to 2 feet in height, thus the water ran round the four sides of the sand-bag enclosure (leaving the interior comparatively dry) to the pump well, which latter was not taken down to rock, but simply 2 or 3 feet into the gravel. This last arrangement was an improvement on what had been formerly done, as it not only decreased the lift of the water, but also, when filling in with masonry, the disturbance of the mortar by the rush of the water towards the pumps was avoided. The excavation of the gravel was then carried on, the leakage, which even now existed to a considerable extent, being baled out with iron buckets, and afterwards by a contractor's pump (which was subsequently obtained from another office, and which proved most useful) outside the sand-bag wall, whence it ran into the pump well.

When the rock was reached all over the pier, site levels were taken, and the lowest third part was surrounded by a sand-bag wall resting on the rock itself, thus this portion remained dry while the leakage flowed into, and was baled out of the remaining two-thirds of the excavation.

The rock was carefully cleaned, chiseled, and levelled, and the first two courses laid. In places where the water dripped into, or interfered with the masons, it was diverted by means of channels formed of stout iron pegs driven into the sides of the excavation, on which were placed planks having a considerable transverse cant, and a slight longitudinal slope, the planks forming with the nearly perpendicular sides of the gravel a misshapen letter V; the point of the V, and any joints in the planks were plugged with clay.

When one portion of the foundations had been raised two courses, another was undertaken, and so on till the whole was complete;

each outside joint of the masonry was pointed with very stiff clay, so as to protect the mortar from the wash of the water while it was setting.

The lowest point of the rock bed was taken in hand first, and the thickest stones used, for the reason that the stones being 12, 11, 10, and 9 inches thick, the slope of the rock could be levelled off in steps, and all the top of the first course got exactly level without using thin stones; and with the least labour all the stones were let into the live rock slightly, so as to preclude all danger of slipping.

One pier was purposely pushed on somewhat faster than the second, as neither skilled labor, nor materials would have sufficed for carrying on the masonry work of both equally fast; but by the 10th May, or in two months from first breaking ground, the foundations of one pier were completed, and those of the second were well up, and out of danger of being silted up by floods, and both piers were well advanced before the commencement of the monsoon. This was a most satisfactory result as compared with the time expended over the previous foundations, particularly when it is borne in mind that during the season of 1876 there was no night work beyond keeping the engines pumping, sometimes one, sometimes two, as occasion demanded, whereas, in the season of 1875, night gangs were more often employed than not. One point deserves particular attention, which is that, in open pits especially, when the soil is loose, the water should, if possible, never be allowed to rise when once taken down, otherwise, not only does the water penetrate in every direction far into the soil, occasioning great delay and expenditure of fuel in its reduction, but also, in sinking, it loosens and disturbs the sides of the pit, which, if not very firmly secured, are liable to fall, whereas the dry sand stood firmly at very steep slopes. In fact, it was found advisable to get up steam about 5 p.m. in one engine, and commence working it at 6 p.m., the hour for knocking off work, when the other two engines were stopped to be cleaned, oiled, &c. By about 9 or 10 p.m. the water would have risen almost to the level of the lower pumps, when a second engine would be started. About an hour before work commenced, all three engines would be worked to get the pit dry for the workpeople, and, when this had been effected, the engine that had worked all night would knock off during the day. It is difficult to give the exact amount of fuel required, as so much depended on the depth of the pit, on the way in which the engines worked, and on the number of stoppages that took place during the day, but a fair average was found to be 12,000 lbs. of fairly dry babool wood, when all three engines were worked during the 24 hours (not necessarily all at once, as that seldom occurred for more than a very short time). From first to last 1171 tons of firewood were used in excavating 80,000 cubic feet of "excavation proper," or say $1\frac{1}{4}$ tons per 100 cubic feet, which, at the average rate of 10 rupees per ton, gives about 13 rupees the cost of fuel per 100 cubic feet, but it must be borne in mind that *all* the fuel was charged to excavating foundations, whereas, in truth, some of it was expended while the pits were being refilled with masonry work, and also that the pits were made very much larger than the "excavation proper." The cost of excavating in sand and water amounted to 48 rupees per 100 cubic feet; this includes repairs to engines, oil, tallow, fuel, driving belts, engine men and overseer's pay, planks, piles, in fact, all expenditure that could fairly be charged to that item, in addition to the actual excavation of the soil. A few notes of the quantity of water discharged by the pumps at different times were recorded, and may be of interest.

The Clayton and Shuttleworth's double cylinder 12-H.P. engine.

Length of stroke, 12″ ... ... } Area of each 53·46
Diameter of piston, $8\frac{1}{4}$″ ... ... } square inches.

With a boiler pressure of 37 lbs. this engine made 84 revolutions, or 168 single strokes per minute, and, with an 8-inch centrifugal pump and leather driving belt, it raised the water 18 feet, and discharged 18·75 square inches of water at the rate of 10·6 feet per second.

This gives exerted H.P. = 20·2
And effective ,, = 3 nearly.
And modulus of system = 0·15

Young's single cylinder 10-H.P. engine.

Diameter of piston, $11\frac{1}{2}$″ ... ... } Area 103·87 square
Length of stroke, 16″ ... ... } inches.

With boiler pressure of 40 lbs. this engine made 72 revolutions, or 144 single strokes per minute, and, with an 8″ centrifugal pump and leather driving belt, it raised the water 15′, and discharged 45 square inches of water at the rate of 10′ per second.

This gives exerted H.P. = 24·2
And effective ,, = 5·3
And modulus of system = ·22

Dunlop's single cylinder 6-H. P. engine.

Diameter of piston $6\frac{3}{4}$″ ... ... } Area 35·78 square
Length of stroke 12″ ... ... } inches.

With boiler pressure of 25lbs. this engine made 64 revolutions, or 128 single strokes per minute, and with a 5″ centrifugal pump and leather driving belt, it raised the water $10\frac{1}{2}$ feet, and discharged 382·5 gallons=3825 lbs. water per minute.

This gives exerted H.P.=3·46
And effective „ =1·22
And modulus of system = ·35

The same engine and pump, with 40 lbs. boiler pressure, made 72 revolutions, or 144 single strokes per minute, and raised the water 12 feet, and discharged it 17 square inches at the rate of 10 feet per second.

This gives an exerted H.P.=6·2
And effective „ =1·6
And modulus of system =0·26

These figures and results are excessively rough; for instance, it is known that the boiler pressure is greater than that which acts on the piston, but it is thought that they may be useful by way of comparison.

In conclusion, a few remarks may be added on the description and prices of materials used, and the quantity of work done by the masons.

The lime used was very markedly hydraulic, and known in the country as kunker lime; it was either picked up in the fields in the form of nodules, or dug out of quarries from four to six miles from the bridge site; it was burnt in the ordinary country kiln with charcoal, and, after being screened through a sieve of $\frac{1}{16}$-inch meshes, was supplied by contract at the rate of 25 rupees per 80 cubic feet. The sand was obtained close at hand at the rate of 15 annas per 80 cubic feet. The mortar used in the superstructure was composed of two parts sand to one of screened lime, that for the foundations—in order to be more hydraulic—consisted of one part of lime, one of sand, and one of burnt clay finely powdered, and made a very quick-setting mortar. At first powdered bricks and tiles were used at considerable cost, but eventually it was found that the clay and silt taken in rough lumps from the vicinity of the bridge, and burnt in the ordinary lime kilns—a 1-foot layer of clay requiring a 6-inch layer of wood—answered equally well, and was very much cheaper.

The stone quarries were from three to four miles distant up the the sides of steep hills: the stone was a very hard black description of amorphous trap, which was found in the shape of boulders under the surface; these were dug out if very large, broken by blasts, and rolled down the hill, where they were knocked roughly into shape with large hammers, and were then brought on the work.

The following are the contract rates given for the stones in the rough:—

Face stones, or khaudkees, length 1′ 6″ to 2′; breadth at one end 1′ to 1′ 6″, tapering towards the other end; thickness at one end 9″ to 12″, tapering towards the other end—

2′ × 1′ 6″ × 9″ to 1′	$23\frac{1}{2}$ rupees per 100.
1′ 6″ × 1′ × 9″ to 1′	12·12 rupees per 100.

Face headers, which were in the proportion of 1 to 5 of the face stones, were similar in shape to the latter, but longer; their prices were—

4′ in length	14 annas each.
$3\frac{1}{2}$′ "	9 "
3′ "	7 "

Rubble headers, to be placed in the rubble hearting of the work, had no face, but were not to be less than 6 inches thick at any point; their prices were—

4′ in length	10 annas each.
$3\frac{1}{2}$′ "	6 "
3′ "	4 "

Corner stones, 9 inches to 12 inches thick

Rate, 2′ × 1′	8 annas each.
" $1\frac{1}{2}$′ × 1′ ...	6 "

Arch slabs, $2\frac{1}{4}$′ × $1\frac{1}{2}$′ × 10″...	40 rupees per 100.
" $2\frac{1}{4}$′ × 1′ × 10″	30 " "
Arch quoins, $2\frac{1}{4}$′ × $1\frac{3}{4}$′ × 12″	100 " "
" $2\frac{1}{4}$′ × $1\frac{1}{4}$′ × 12″	75 " "

Good sound rubble or quarry shivers, each piece not less than $\frac{1}{8}$ cubic foot, four rupees per 100 cubic feet.

The dressing of these stones was given in petty contract at two annas per foot run of the face, the agreement being that the stones were to be exactly 9 inches, 10 inches, 11 inches, or 12 inches in height; side joints dressed back true and square with the face to a distance of 4 inches, the tails being left rough; the beds of face stones 6 inches to 8 inches; and those of face leaders 9 inches to 12 inches, the tails being left rough. With this rate the masons provided their own steel, soft iron, hammer buts and a smith being allowed them, and it was found to be a hard day's work to earn their usual daily wage.

Thirty rupees per 100 cubic feet of superstructure, and twenty-eight rupees per 100 cubic feet of filling in foundations, was found to be a very fair rate to cover all expenses; the description of work was exactly similar in both, but, in the former, batter and cut waters had to be given, the amount of rubble hearting or cheap work was less, and the materials had to be raised a considerable height; if a proportion of the pumping had been charged against "filling in foundations," as it might have been, instead of only against "excavating," the rate would have been considerably higher.

It was noted in filling in the foundations over an area of 40×10, that twelve masons could lay the face stones of two courses, or about 160 stones ready dressed as above described, and ten masons could fill in the corresponding rubble hearting easily per diem, and this was a good rate, ensuring good sound workmanship; this gave about 13 to 14 face stones per man, and 22 cubic feet of hearting per man. The number of coolies per mason depends, of course, entirely on the distance the materials have to be carried; in ordinary cases three is found sufficient to cover all requirements.

The daily wages of masons varied from 6 to 12 annas, of coolies from 2 to 3 annas.

The piers being 43 feet in height, 9 feet wide at bottom, and 6 feet at top, the side batter was $1\frac{1}{2}$ feet in 43. The centres and radii of the arcs of the cut waters varied with each course, the radii being, for instance, at the bottom 9 feet, and at the top 6 feet, and the arcs, of course, tangential to the sides of the pier—this gave a very pleasing effect; the following method was adopted to obtain the correct batter and radii, and was so simple that, after having once learnt it, the common masons carried on the work perfectly correctly. A rod was worked at its centre, and also at $4\frac{1}{2}$ and 3 feet on either side of the centre, this gave the pier width at base and top respectively; the space between the last-mentioned two marks, namely $1\frac{1}{2}$ feet, was again sub-divided into four equal spaces of $4\frac{1}{2}$ inches each, these gave the widths at 10 feet 9 inches, 21 feet 6 inches, and 32 feet 3 inches above the base; a scale was also made showing the amount of batter in every inch of height of the pier for a height of 10 feet 9 inches; then, the height of the pier above base being known, the amount of batter was deducted on the rod, and gave the width at the level required. For instance, suppose the pier to have been raised 10 feet 9 inches, the correct width for which is already marked on the rod as the first division, and it is proposed to lay a 10-inch course. The four stones, in which the centres of the arcs will come, are first of all laid, and the half-widths of the bridge are accurately laid off from the marked axis of the bridge along both faces of the pier and marked; a line parallel to the axis of the bridge joining a pair of these marks will contain the centres of the new arcs. The rod is laid along this line with its centre placed vertically over a line joining the noses of the pier in the completed course, and the correct half-width is laid down, and gives the centres for the new course. The arc for the cut waters is then struck with a beam compass from the new centres, and can be dressed accurately to a hair's breadth, the sides of the piers are also completed, and the half-widths of the piers measured inwards give the bridge axis for the new course, which is carefully marked; the next course is then proceeded with in an exactly similar way, the great point to be remembered is never to cover up the marks showing the bridge axis until the centres of arcs of the upper course are accurately marked, and *vice versâ* never to cover the centres of arcs until the bridge axis is carefully marked on the course just completed; by adhering rigidly to those rules it is impossible to get wrong in the batter. The supervising officer at his periodical visits will check the level of the course in progress by means of a spirit level and a bench mark on the adjacent bank, and tell the masons their next height above the base of the pier.

In conclusion it may be mentioned that hundreds of piles, ranging up to 16 feet in length, were driven by the Swiss method, as described by Lieut. Bucknill, R.E., in an old number of the R.E. Papers; that is to say, a hole was bored in the head of the pile in the direction of its axis, into which a crowbar acting as a guide to the monkey was wedged. The monkey consisted of a piece of wood in the form of a frustrum of a cone, in the axis of which a hole was bored, the diameter of which was somewhat longer than that of the crowbar. Four iron handles were attached to the monkey by means of wrought iron screw bolts, and by these the monkey was worked. When the piles were long and took some time in driving, it was found advisable to have a platform on which the man could stand; this consisted simply of a frame about 4 feet square, on which were nailed planks leaving a space sufficient for the pile to just pass through in the centre. The platform was supported by four rough struts, to the lower end of which were affixed iron hooks which fitted into eyes in an iron collar; the latter could be clamped at any convenient height to the pile, and the whole platform descended with the pile. When the collar touched the ground it was unclamped and cast off, as were the struts, the platform remaining lying on the ground until the pile had been driven, when it was lifted up and removed.

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LIEUT., R.E.

PAPER VIII.

TARGETS

FOR THE

TRIAL OF RECENT HEAVY ORDNANCE.

PART II.

BY COLONEL T. INGLIS, R.E.

BEFORE resuming the subject of the Armour Plate trials commenced in No. 1 of this volume, it is considered desirable that a round from the 38-ton gun against masonry should be briefly noticed.

THE 38-TON GUN AGAINST A GRANITE FACED WALL.

The structure used for this trial was a wing wall which formed part of the old casemates set up at Shoeburyness for experiments in 1865. It is shown in *Plates* I. and II

This wall was originally faced with armour plates (since removed), and in the trials described at p. 265, Vol. XVIII., of *Corps Papers*, it was more or less injured, some of the granite blocks being cracked, and the work generally a little shaken and disturbed. Still, the granite block, on which the shot in the present trial was planted, had never been hit before, and, so far as could be judged, the brickwork and concrete behind it were quite sound.

It should be explained that the granite blocks were not dowelled or cramped together; but the long bolts, which had formerly held on the armour plates, were still in the wall, and served to some extent to tie it together. There was no iron bond in the brickwork.

The present trial took place on the 9th of January last. The photographic number of the round is 2040.

The projectile was a 12·5-inch Palliser service shell, fitted with a gas check, and weighted with sand up to 822 lbs. The charge was 130 lbs. of pebble powder; the range 70 yards; the striking velocity of projectile about 1,405 feet per second, giving an energy on impact equivalent to 11,250 foot tons.

The shell struck perpendicularly to the face of the wall, but feeling the least resistance to be on the left, it inclined considerably in that direction.

The path taken by the projectile is shown in *Plates* I. and II., from which it will be seen that it passed through upwards of 5 feet 6 inches of granite, and a like thickness of brickwork and Portland cement concrete, and was found lying on the floor of the casemate. The shell was unbroken, highly polished, with spiral markings formed by its rotation while passing through the wall, the studs only were partially rubbed off, and the gas check was still attached.

The wall was completely wrecked. It seemed to have been lifted bodily, and was torn asunder in all directions. Immediately around the shot mark the granite was broken small and thrown out to the front, the cavity measuring roughly 8 feet by 7 feet, and 5 feet in depth. Every stone in the wall was knocked out of place, and large masses of the brickwork were thrown down. More of these would have fallen had they not been caught by the armour bolts before referred to.

It would have been interesting to compare the effect of this blind shell with a live Palliser shell (bursting charge 12 pounds) from the same gun, but the wall was so much injured that this could not be done.

The Chambered 38-Ton Gun against No. 40 Target Strengthened with a Fourth $6\frac{1}{2}$-inch Plate.

At page 3 of No. 1 a description is given of No. 40 target as at first opposed to the 38-ton gun. It then consisted of three $6\frac{1}{2}$-inch plates with 5-inch thicknesses of teak between them. Also it was intimated in that Paper that this target was about to be strengthened by adding another $6\frac{1}{2}$-inch plate in readiness for the trial of the 38-ton 12·5-inch gun, after its powder chamber should have been enlarged to a diameter of 14 inches.

This was accordingly done. The additional $6\frac{1}{2}$-inch plate, measuring 8 feet by 6 feet 8 inches, and covering, therefore, two-thirds of the front of the target, was bolted on by six 3-inch bolts of the same pattern as those in the rest of the target, and the interval of 5 inches behind this plate was filled with teak arranged as in the other intervals.

There were thus four $6\frac{1}{2}$-inch plates with three 5-inch thicknesses of teak now opposed to the gun.

It may be here stated that a piece of this additional $6\frac{1}{2}$-inch plate was proved with a 7-inch Palliser shot of 113 lbs., fired with 12 pounds R.L.G. powder at 30 yards range; striking velocity, 1,162 feet; energy, 1,055 foot tons; and that the indent was 7·75 inches deep, a star crack only being formed on the back of the plate. It therefore received the highest figure of merit.

The timber structure in rear was made good in the parts injured in the first trial.

The round now fired has been numbered 2,043. The trial took place on the 16th March, 1877.

The gun was placed as before—range, 70 yards.

The charge used was 200 lbs. of $1\frac{1}{2}$-inch cubical powder, or 70 lbs. more than in round 2,039. Owing to some difficulty experienced in ramming the charge home in one cartridge, two separate cartridges were placed in the gun, and as these occupied a somewhat greater length of bore than was intended, there was a certain falling off in the velocity obtained. Instead of a muzzle velocity of about 1,570 feet per second, which was expected, one of 1,536 feet only was obtained, and this was reduced to about 1,525 feet at the target. The energy on striking was thus about 13,080 foot tons, or 1,680 foot tons more than in round 2,039, instead of 13,580 foot tons as expected.

The exact diameter of the shell was 12·4 inches over the body, its length was 33 inches. It was a service Palliser shell weighted with sand up to 800 lbs., and fitted with a gas check which weighed $11\frac{1}{2}$ lbs. The shell struck on a point 2 feet $5\frac{1}{4}$ inches from the proper left edge of the additional $6\frac{1}{2}$-inch plate, and 3 feet 1 inch from the top of the target.

On entering the front plate, the shell felt the least resistance to be on its proper right side, and therefore turned in that direction at an angle of about 5° from the perpendicular.

It penetrated the target until its point got somewhat less than an inch into the back plate. It there remained embedded in the target with its gas check still attached to it, the depth from the face of the front plate to the base of the shell being 8·2 inches. On removing the gas check only two pieces of the shell were found to be broken off it, the rest of the projectile being in an unusually entire state. The hole in the front plate was $12\frac{1}{2}$ inches in diameter and quite circular.

The front of the target was not driven back more than $\frac{1}{2}$-inch. The front plate was buckled about $\frac{1}{10}$ of an inch. In rear the back armour plate was buckled about 3·4 inches, and there were faint surface cracks over a length of 10 inches immediately opposite the head of the shell. A crack, about 2 feet 6 inches long, extending obliquely upwards from the shot hole of round 2,039 to the neighbourhood of the present injury, was formed in the back plate, and an armour bolt, holding the back plate to the one in front of it, at a distance of about 3 feet 6 inches from the shell, was found to be broken, but the exact nature of its fracture has not yet been ascertained. The timber supporting structure in rear was very little injured.

It may here be mentioned, that the strengthened part of this target having thus proved itself to be more than a match for the chambered 38-ton gun, it is now intended to place a 3-inch plate on the present unstrengthened part of it, and to endeavour to obtain with this an exact measure of the power of the gun when throwing its service Palliser shell with the full muzzle velocity of 1,570 feet per second.

It is also expected that we shall shortly have an opportunity of comparing round 2,039 with one at a solid armour plate, $16\frac{1}{2}$ inches thick, from which we may hope to gain valuable experience.

Palliser Shell at Armour Plates with Void Spaces between them.

At page 5 of the former number of this volume, the question of the breaking up of Palliser projectiles, when used against armour plates with void spaces between them, was revived, and a description was given of a round fired from the 38-ton gun at a 10-inch plate standing before a 4-inch plate. After that trial, it was determined to follow up the matter a little farther, and to try the effect of reversing the order of the plates before used, at the same time reducing the distance between them.

The 4-inch plate was, accordingly, now placed in front of the 10-inch, and the space between them reduced from 6 feet 8 inches to 4 feet 7 inches, The same nature of gun and projectile was used as before; but as, in the meantime, the gun had been chambered, the charge of 175lbs. of $1\frac{1}{2}$-inch cubical powder was used to give the same velocity as that in the previous round, when the charge was 130lbs. of $1\frac{1}{2}$-inch powder in the unchambered gun.

The shell was filled with sand, and weighted up to 800lbs.

The round was fired on the 27th March; photographic No. 2,046.

The effect upon the shell was even more marked than before. It passed through the 4-inch plate, making a hole $12\frac{1}{2}$ inches in diameter, and, breaking up in doing so, a quantity of it was found in a state of "splash" upon the face of the 10-inch plate. The "splash" covered an area of about 2 feet by 1 foot 6 inches, and stood out from the face of the plate about 4 inches at its highest part. The 10-inch plate was comparatively but little injured; the bulge on its back being not more than $\frac{3}{4}$-inch high.

Thus, a $12\frac{1}{2}$-inch shell, with an energy of about 11,400 foot tons, which in round 2,039 has been proved to be equal to the perforation of three $6\frac{1}{2}$-inch common plates, on this occasion did little effective work beyond that of perforating a 4-inch plate, and damaging the face of a 10-inch plate with a consequent slight bulge on its back.

It is hoped that before long this round will be followed by one from the same gun at a 4-inch plate, placed only 1 foot 6 inches from a 10-inch plate, and also by another at a 4-inch plate placed a short distance in front of granite.

Common Shell at Unbacked Armour Plates.

It was mentioned at the end of the paper in No. 1, that a service common shell from the 80-ton gun had passed through an 8-inch armour plate.

In continuation of this experiment, two rounds have now been fired from the 10-inch 18-ton gun with the following results:—

In round 2,044, a common shell of service pattern, weighing 400lbs., and containing a bursting charge of 26lbs., was fired with a charge of 70lbs. of pebble powder at a range of seventy yards. It was not fuzed. The armour plate was 5 inches thick, and measured 7 feet 6 inches by 3 feet. It was unbacked. The shell passed through the plate, and broke up in doing so, the explosion of the bursting charge apparently taking place after the shell had got through the armour.

Round 2,045 was fired with the same projectile, charge, and range as before, except that a Pettman general service fuze was used in this shell. The plate this time was also 5 inches thick, and unbacked, but it was held more firmly than the last plate. The bursting of the shell now took place at the moment of its passing through the plate, and was, no doubt, caused by the action of the fuze.

These rounds will help to correct the mistaken notion, which has been very general, that only a slight thickness of armour is necessary for keeping out *common* shell.

The Chambered 80-Ton Gun against No. 41 Target.

In concluding the notice, in No. 1, of the first round from the 80-ton gun against this target, it was announced that in all probability the next round fired at it would be from the same gun after it should have been chambered.

This having come off on the 4th of May, the result is now reported. Photographic number of round, 2,047

The only alteration made in the gun since the last trial, consists in the enlargement of the bore from 16 inches to 18 inches for a length of $58\frac{1}{2}$ inches to form a powder chamber. By this means, a greatly increased charge of powder can be used without increase of maximum pressure in the bore, and, therefore, in a certain degree, the power of the gun is improved without subjecting it to increased strain.

On the last occasion, it will be seen, a muzzle velocity of about 1,510 feet per second was given to a 1,700lbs. projectile by a charge of 370lbs. of powder, with a maximum pressure in the bore of something under 22 tons to the square inch. This velocity denotes an energy in the projectile, on its leaving the muzzle, of about 26,878 foot tons

Now, with the enlarged chamber, a charge of 425lbs. of the same kind of powder—$1\frac{1}{2}$in. cubical—has given a muzzle velocity of 1,600 feet per second to the same projectile, with a maximum pressure in the gun supposed to be less than before. This velocity represents an energy of about 30,177 foot tons, or an increase of work, due to the additional 55lbs. of powder, of about 3,300 foot tons.

The range this time was 130 yards. The axis of the bore of the gun was inclined at an angle of about 2°, in the horizontal plane, to the perpendicular to the face of the target.

The projectile was of the same nature as that used in round 2,041; that is to say, it was a Palliser shell, with a head cast in chill, and struck to a radius of one diameter and a half of the body, which was cast in sand. The outside diameter of the shell was 15·925 inches measured over a band at its base. The general diameter of the body was 15·8 inches. It had four rings of gun metal studs, with 13 studs in each ring, 1·2 inches to 1·45 inches in diameter, standing 2 inches out of the body of the shell. The length of the shell was 42 inches. The shell was weighted with sand to 1,700lbs., including its copper gas check, and plugged.

The velocity was about 1,585 feet per second at the target, which denotes an energy of about 29,615 foot tons on impact.

The target has already been fully described.

The point of the shell struck the armour 6 feet from the proper left of the target, 3 feet from its top edge, and 5 feet 9 inches from the centre of the shot-hole of round 2,041.

The diagrams in *Plate* III. show the penetration and general effect upon the target.

The hole made in the front armour plate is perfectly round, and 16·05 inches in diameter, measured three inches in from the face of the plate, showing that the projectile was quite steady in its flight at the instant of impact. Across the circle of "lip" the hole measured 18·6 inches, and across the outer circle of injury, formed by the breaking away of a ripple raised at some stage of the entry of the shell, the diameter is 20½ inches. There are no cracks whatever in the front armour. The front of the target was driven back at the proper right end (that nearest the shot mark) 1·2 inches at the lower part, and 2·8 inches at the upper part, giving an average of 2 inches of backward movement. At the other end it moved forward 2·75 inches at the bottom, and one inch at the top, giving 1·875 inches of mean forward movement.

It will be seen from the diagrams that the shell took a very straightforward course in penetrating the target; in fact, its axis was throughout as nearly as possible square with the face of the front plate. The shell broke up much more extensively than that in round 2,041, but still it is to be observed that every portion of it entered the target, as there are no signs of any pieces having grazed the face of the front plate.

It will also be observed that the actual penetration of the point of the shell into armour in this round is only one-third of an inch more than that in the former round; but the total penetration measured from the face of the target is 7·4 inches more, the difference being accounted for by the greater amount of bulge in rear.

The shell struck close to an armour bolt in the front plate, and also close to one in the second plate. These, of course, have been more or less injured, but the rest of the bolts have stood perfectly well, and their behaviour justifies the conclusion drawn from the former round as to 3-inch bolts being sufficient for the heaviest armoured structures, if used in proper numbers, and applied in the proper manner.

Beyond the injuries shown in the diagrams, there is nothing to notice except a very faint appearance of separation of the moulds of the rear armour plate on part of its left edge.

The timber structure in rear of the target stood remarkably well. There is no appearance of the entire mass having been driven back, though, of course, the parts near to the armour have been more or less compressed, and slightly splintered.

It was said in reviewing the effects of round 2,041, that that shell would, in all probability, have passed completely through the target had it been composed of only three 8-inch plates instead of four.

In the same way it may be said that probably the shell in the present round would have passed quite through the target, if any one of the four plates of which it is composed, had been about 2 inches instead of 8 inches thick, or if there had been four plates $6\frac{1}{2}$in. thick, or three $8\frac{1}{2}$-inch plates.

The theoretical equivalent in thickness of solid plate for either of these three supposed cases, I should roughly put at 23 inches; but it is hoped that before long we shall be in possession of data for more reliable comparison between solid and plate upon plate structures of great thickness.

Armour Plate Experiments in Italy in 1876.

It will probably be thought that this paper should contain some notice of the extensive experiments made, last year, by the Italian Government, at Spezia, more especially as, on that occasion, the powerful rival of the Woolwich eighty-ton gun was employed against armour.

To begin with the targets, there were the following:—*

1. A target consisting of two front plates of soft hammered steel, $21\frac{3}{4}$ inches thick, and 10 feet 6 inches and 11 feet 6 inches long respectively, by 4 feet 7 inches in width, made by M. Schneider, of

* English weights and measures are used in these descriptions.

Creuzot. These plates were backed by 28 inches of oak, (in which there were horizontal iron stringers of $\frac{1}{2}$-inch plate 10 inches deep, rivetted to angle irons at frequent intervals), covering a skin of two thicknesses of $\frac{3}{4}$-inch plate, the target being supported in rear, at the ground line, by massive horizontal timbers of oak, and, at the top, by iron deck beams, inclined downwards to the rear, so as to form struts abutting against oak piles.

The upper plate was held by sixteen armour bolts, screwed five inches into the back of the plate, and the lower by fourteen similar bolts. These bolts were $4\frac{1}{2}$ inches in diameter over the thread, and their shanks were gradually reduced from 4 inches to $3\frac{1}{2}$ inches. They had $\frac{3}{8}$-inch jackets over their shanks, to make them up to the diameter of their screwed part.

2. A target composed of two wrought iron armour plates of nearly the same dimensions, and the same thickness as the steel plates in No. 1, and with the same arrangement of backing and supporting structure behind them. One plate was rolled by Messrs. Cammell and Co., of Sheffield, the other was made at the works of Messrs. Marrel, of Marseilles. Each plate was held on by seven 5-inch bolts, with conical heads and shanks reduced to $4\frac{1}{2}$-inch diameter through a length of $11\frac{1}{2}$ inches. The hexagon nuts at the rear end of these bolts were fitted with india rubber washers in wrought iron cups.

3. Two "sandwich" targets, each consisting of a front plate of iron 11·8 inches thick, with 12 inches of horizontal timbers behind it, a second plate 9·8 inches thick with 16 inches of wood behind, and skin and frames as before. The armour of one was rolled by Messrs. Cammell, of Sheffield, and the other by M. Marrel. Their length and width were the same as in the other targets. Each of the front plates was held by seven 5-inch coned-headed bolts made by Messrs. Cammell, and each back plate by five $2\frac{1}{2}$-inch bolts of similar pattern. The bolts holding the front plates passed through the second plates.

4. Two targets, consisting, in front, of 7·8-inch wrought iron plates, made by M. Marrel, backed by blocks of "Gregorini" chilled cast iron $13\frac{3}{4}$ inches thick. Each armour plate had four of these blocks behind it; in one case the chilled blocks came next behind the armour, in the other 12-inch timbers were interposed. The structure in rear was the same as before. Each armour plate was held by six bolts passing through holes in the chilled blocks.

5. In addition to these, there was another rolled armour plate $21\frac{3}{4}$

inches thick, made by Messrs. Brown, of Sheffield, which was of the same dimensions, and set up in exactly the same way as those in the second target described above.

Thus, it will be observed, there was in all the targets the same total thickness of about 4 feet 4 inches, made up of about 22 inches of armour, 29 inches of timber, and $1\frac{1}{2}$-inch of iron skin.

It should also be particularly observed that in every target the width of the armour plates was limited to 4 feet 7 inches, and it is owing to this circumstance that, at any rate so far as affording data for calculations of the resisting powers of armour, the results obtained in these, otherwise carefully planned, trials are inconclusive and unsatisfactory.

Next, with regard to the guns.

The principal feature in these trials was the employment of the first of the 100-ton guns which are being made in this country by the Elswick firm, for the Italian Navy, and which are the most powerful guns that have as yet been produced. A short description of this gun may, therefore, be useful here.

In the first place, it is built on the Woolwich principle, that is to say, it consists of an inner steel tube strengthened by successive coils of rolled and welded wrought iron bars.

The steel tube is in two lengths. At the breech there are three layers of coils over the steel tube, at the trunnions two, and on the chase one coil tapering towards the muzzle.

It is made for muzzle loading, it weighs 100 tons, its total length is 32 feet $10\frac{1}{2}$ inches, its breech diameter is 6 feet 5 inches, its calibre 17 inches, the length of bore 30 feet 6 inches, its rifling poly-groove, with twenty-seven grooves, increasing in twist from 1 in 150 to 1 in 50 calibres. The gun was not chambered at the time of the trials, and it is not known whether it will be hereafter.

The projectiles used in the trials were Palliser shells, with chilled heads, made at Elswick, weighing 2,000 lbs., with a capacity equal, perhaps, to 25 lbs. of powder, but none of them had bursting charges. They were 49 inches long, and their heads were struck to a radius of $1\frac{3}{4}$ diameter of the shell.

The powder used was chiefly Waltham Abbey $1\frac{1}{2}$-inch cubical powder, and the gun was fired with charges ranging up to 374 lbs., with which an energy of about 33,000 foot tons was developed;

but the heaviest charge used against the targets was 341 lbs., which gave an energy to the shell of about 31,200 foot tons.

The projectiles were not studded, but they were fitted with gas checks on their bases, by means of which rotation was given to them in, I believe, a satisfactory manner.

The gun was mounted on a special carriage placed on a floating pontoon, which had engines on board for supplying hydraulic power to the gun.

The carriage was of novel construction, and consisted of little more than two metal blocks, in which the trunnions of the gun were set, and which were free to slide on two heavy beams fixed to the vessel. These blocks were controlled for the recoil and forward movement of the gun, by two hydraulic presses behind them, which acted directly upon the blocks. Under the breech of the gun there was a beam hinged at its rear end on a fixed horizontal bar, and actuated by a vertical hydraulic press placed underneath it. To the underside of the breech of the gun a metal block was attached by means of two iron bands and a pin, and this block carrying the breech of the gun recoiled along the beam just described, or bore upon it when at rest. The purpose of this arrangement was not only to give elevation and depression to the gun, but also to provide for a certain diminution in the height of the port of the turret in which this gun will hereafter be mounted, for it is plain that, as the trunnions recoil horizontally, and the rear end of the beam carrying the breech is on a fixed pivot, whatever may be the elevation at which the gun is fired, it will lower its muzzle during recoil and be ultimately brought up in one constant position, which is, I believe, nearly horizontal. The total recoil allowed for was only about 4 feet 3 inches.

The two 100-ton guns to be mounted in each of the turrets of the Italian ships "Duilio," and "Dandolo," will be on carriages of this pattern, and it is believed that it will also be adopted for the 80-ton guns in H.M.S. "Inflexible."

For sponging and loading, the muzzle of the gun is depressed until it comes opposite to, and in prolongation of, an hydraulic telescopic sponge and rammer under a glacis, similar in principle to those fitted on board H.M.S. "Devastation" and "Thunderer." The cartridge and shot were rammed home together, and the telescopic staff was brought back by wire ropes fastened to the sponge head.

As there was no provision for training in the carriage or slide, the gun was laid by hauling the pontoon to the right or left as required.

The other guns used in the trials were a 10-inch, of a little over eighteen tons weight, which threw a Palliser projectile of 397 lbs., with a charge of 77·2 lbs. of powder, and an 11-inch of 25½ tons, which threw a Palliser projectile of 531 lbs., with a charge of 94·6 lbs. of powder. No bursting charges were used.

The 100-ton gun was placed at about 110 yards from the targets, the others at 81 yards.

The trials took place in October, November, and December, 1876, at Spezza. Certain English Officers were present during the experiments, and after the most important rounds had been fired, Captain English, R.E., was sent by our Government to examine the results, and it is partly from that Officer's report that the following particulars of the effects on the targets are taken.

Beginning with the first target, the upper steel plate received first a shell from the 10-inch gun, initial velocity 1,401 feet per second, on a spot 24 inches from the right end of the plate, and 24 inches from its bottom edge. The depth of the indent was about 11 inches, the diameter of the hole 10 inches horizontally, and 13 inches vertically. The plate was cracked from the shot mark to the bottom edge, and after a short interval the plate began to sing, and another crack gradually opened, which also extended to the bottom edge. In rear a few rivets were broken in the supporting structure.

The same plate was next struck by a 10-inch and 11-inch shell fired in salvo. These struck respectively 17 inches and 25 inches from the other (left) end of the plate. The end of the plate was broken away, and fell in three principal fragments, the singing again took place, and the cracks formed by the first round of 10-inch shell were extended, while a fresh one near that round also appeared for the first time. A few rivets and a bolt in rear were broken.

The next (that is the fourth and last) round at this plate was from the 100-ton gun. The initial velocity of the shell was 1,495 feet per second, representing energy equivalent to about 31,000 foot tons. This struck 4 feet 3 inches from the left end of the plate, and 2 feet 7 inches from the top. The point of the shell entered 21 inches into the steel, and completely broke up the plate, only two pieces of it remaining on the target. The rest of it was thrown away in pieces varying from one to three tons in weight. The shell got deep into the backing, but did not perforate it, though the structure was considerably injured. The fracture of the plate was in appearance that of good Bessemer steel.

A similar round to the last was fired at the lower steel plate on the first target, the velocity this time being about 1,476 feet per second, and the energy about 30,200 foot tons. It struck about 2 feet 9 inches from the top, and 5 feet 8 inches from the left end, and its point entered the steel to a depth of 20 inches. The plate was completely broken up by this one round, about one half of it being knocked off, the rest being left hanging by some of the armour bolts, and some portions of the plate continued to crack and fly for some minutes. The shell penetrated some depth into the backing, but, as before, did not perforate it; the damage done to it, however, was very serious. A number of the armour bolts were broken in the first thread of the screwed part which entered the armour, and some hexagon nuts were broken. The appearance of the steel was much the same as in the other plate.

This completes the trial of the steel armour.

Next, with regard to the rolled iron armour plates, of the same thickness as the steel, on the second target.

Messrs. Cammell's plate was subjected to rounds corresponding with those on the upper steel plate above described, but unfortunately the shell from the 100-ton gun struck so close to the bottom edge that all comparison was lost.

The first 10-inch shell at this plate struck with a velocity of 1,384 feet per second on a spot 24 inches from the right end, and 27 inches from its bottom edge. The depth of indent was 10·8 inches. Cracks, $\frac{1}{8}$-inch wide, were opened from two bolt holes near the corners of the plate to its top and bottom edges respectively. A few rivets were broken in rear.

The 10-inch and 11-inch shells fired in salvo struck near the other end of the plate, and broke off a piece of the corner of the plate through about half its thickness, and broke away another small piece, and formed a large crack from a bolt hole to the upper edge of the plate, besides opening a weld in the moulds on the upper edge. Two armour bolts were driven back by the shell, some rivets in rear and a cup washer were broken in this round. The indents made by these two shells were reported as 17·75 and 13 inches respectively.

The shell from the 100-ton gun at this plate had an initial velocity of 1,478 feet, corresponding with an energy of about 30,300 foot tons; but, as already mentioned, it, most unluckily, hit low, and struck only 10 inches from the bottom edge of the plate, a little to the right of midway in its length. It broke away the bottom of the plate, and split it across through a bolt hole in the upper part, dividing the plate into two nearly equal portions, one of which remained on the target. The shell passed quite through the target, doing, of course, great damage to the structure in rear. The welding of the plate round the shot mark was imperfect, but the quality of the armour was good. Not much, however, is to be learned from this round.

M. Marrel's rolled plate on this target was attacked by similar rounds. The first 10-inch shell struck it with a velocity of 1,397 feet, and indented it to a depth of 11 inches. It struck 2 feet from the end, and 3 feet from the top edge, and formed a crack, from the shot mark through a bolt hole to the bottom edge of the plate, $\frac{5}{8}$-inch wide. The plate was bulged in rear about 1 inch.

The 10-inch and 11-inch shells fired together, struck both about 18 inches from the other end of the plate, made indents $12\frac{1}{2}$ inches and $14\frac{1}{2}$ inches respectively, and broke off the end of the plate, which remained hanging until the next round was fired. One other crack ran to the upper edge of the plate.

The shell from the 100-ton gun was next fired at M. Marrel's plate. It had a muzzle velocity of about 1,500 feet, and energy of 31,200 foot tons. It struck 1 foot $9\frac{1}{2}$ inches from the bottom edge, and 5 feet 5 inches from the right end. The lower part of the plate gave way, and the shell turned down, and went through the target. The depth of indent in the armour was 23 inches, and on the rear of the plate there was afterwards found a bulge 3 inches high, the rear mould, 5 inches thick, being broken off over a circle 3 feet 6 inches in diameter. All the upper part of the plate was carried away, and the rest of it broken to pieces. The backing which had been previously injured by the 17-inch shell at Messrs. Cammell's plate was, of course, greatly damaged by this round. The armour plate had the appearance of being a hard, steely iron, well welded, and the fractures were crystalline throughout.

The only other thick armour plate used at Spezza was that made by Messrs. Brown, of Sheffield, as already mentioned.

This received four rounds from the 100-ton gun, with projectiles of the same nature as those fired at the other solid $21\frac{3}{4}$-inch plates.

The first round took effect on the very edge (lower edge) of this plate, and turning downwards, buried itself deep in the earth.

The next round was fired with a reduced charge of 240 lbs. which gave a velocity of 1,046 feet per second to the shell, and a corresponding energy of 15,175 foot tons. This struck about 2 feet 4 inches from the bottom edge, and 2 feet 3 inches from the right end of the plate, and made an indent 15·2 inches deep, wedging off a triangular piece from the plate by a large crack passing through the former shot mark, the present shot mark, and a bolt hole.

The next round was fired with a charge of 400 lbs., of another kind of powder called "Fossan progressive powder," giving a velocity of 1,500 feet, and energy equivalent to 31,200 foot tons. This struck about 3 feet from the other (left) end of the plate, and 1 foot 9 inches from the bottom edge. It went completely through the target, making a hole about 4 feet wide through the supporting structure in rear, representing the side of a ship, broke off the whole end of the plate and the backing at that part, and produced general ruin.

The fourth round was fired with a charge of 265 lbs. of English powder, which gave a velocity of about 1,296 feet per second, and an energy of about 23,300 foot tons. There was very little of the plate left sound for this shot, but it struck in the middle of what was left, and its point penetrated to a depth of 15 inches into the armour. The plate was split through the shot hole, and some of it was driven about 11 inches deep into the timber backing. The skin was not pierced.

With regard to the "sandwich" structures in the third target, beginning with Messrs. Cammell's armour, the following practice took place.

The first 10-inch shell took effect at 18 inches from the right, and 25 inches from the bottom edge. It struck with a velocity of 1,385 feet per second, and made an indent in the front plate 13 inches deep. There were no cracks in the plate, but some of the surface of the armour plate scaled off 1 inch deep on the left side of the shot mark. The effect in rear of the target was very slight.

The 10-inch and 11-inch shells, fired together, struck 24 inches and 12 inches from the left end, and 24 inches and 20 inches from the bottom edge, with velocities of 1,302 feet and 1,401 feet per second respectively. The front plate was broken across through the shot marks, the lower corner was thrown off, and the upper piece was held from falling by an armour bolt. The indent made on the inner plate by each shell was $2\frac{3}{8}$ inches deep. The 11-inch shell drove a bolt through the target, but the effect in rear was slight, only a few rivets being broken.

The shell from the 100-ton gun struck near to the centre of the target with a velocity of 1,046 feet per second, and energy of 15,175 foot tons. It was fired with a charge of 240 lbs. The shell passed through the front plate, and the penetration into the inner armour plate was supposed to be 6·7 inches. The plate was wedged asunder, a slanting crack being formed across it through the shot mark and two bolt holes, but no piece came off it, and no other cracks appeared. Both plates were much buckled, the intermediate timber was driven out from about the shot mark, the skin was bulged, but no rivets or bolts were broken. This round compares, as regards energy, with that fired at Messrs. Brown's solid plate, in which the indent is given above at 15·2 inches; but the excess of indent in the present round is more than our experience in England would lead us to expect, and I account for it either by supposing the indent to have been incorrectly registered, and when a shot remains in a "sandwich" target without showing its point in rear, it is sometimes extremely difficult to get the exact penetration into the inner armour, or, what is quite likely, the space of 12 inches left in this target between the armour plates is so much in excess of that which has been used on any of our English targets, that the shell met with less than its proper resistance in getting through the front plate, and, in proportion, did more work upon the inner plate.

The "sandwich" structure in the third target, made of M. Marrel's plates, received the same rounds as Messrs. Cammell's.

The 10-inch shell struck 3 feet from the bottom, and 2 feet 6 inches from the right, with a velocity of 1,414 feet, and made an indent $9\frac{7}{8}$ inches deep, but the plate was crackedquite across through the shot mark and two bolt holes, two pieces being ready to come away.

The 10-inch and 11-inch shells, fired in salvo, struck 18 inches from the left, 19 inches from the bottom, and 30 inches from the left, 36 inches from the bottom respectively, with much the same velocities as before. The 11-inch shell made an indent of 2 inches on the inner plate, and the 10-inch shell indented the front armour 13 inches. The front plate was much cracked, and pieces of it were quite detached.

The shell from the 100-ton gun struck about 18 inches from the bottom, and 5 feet 6 inches from the left end. The muzzle velocity was 1,494 feet, giving an energy of 30,960 foot tons. It turned downwards in passing through the front plate, and struck the inner plate only 4 inches from its lower edge. Two pieces only of the front plate remained on the target. The inner plate was broken to pieces. The filling between the plates was almost destroyed, and the structure in rear much broken and displaced. The armour plates in this structure cracked very much more than Messrs. Cammell's.

Lastly, with regard to the fourth target, composed of wrought iron armour plates, with chilled cast iron blocks behind them.

Commencing with that portion in which 12 inches of wood was interposed between the armour and the cast iron, the shell from the 100-ton gun fired with 400 lbs. charge, giving a velocity of 1,494 feet, struck fair on the centre of the left half of the plate, punched a hole through it, measuring 26 inches by 19 inches, broke the cast iron blocks into fragments, which, being propelled onwards, burst through the structure in rear, and formed a great hole about 6 feet in diameter, in what would have been the ship's side. The wreck of this end of the target was complete.

A similar round disposed of the other portion, in which the cast iron came next behind the armour plate. In this case the shell from the 100-ton gun struck near the centre of the right half of the plate, broke its end away, and threw it over the top of the target. In fact, that end of the target was completely demolished by this one round, the fragments of the cast iron aiding greatly in the work of destruction.

It may be mentioned that the cast iron blocks were chilled only about 1 inch in depth.

In conclusion, a few words may be said on the general results of these trials.

Whether from the nature of the material used in the armour plates, or from their narrowness, or from certain peculiarities in the construction of the targets, the distinguishing feature of these trials is the *cracking* of the plates.

Our experience with steel armour in this country is this—that, whatever ductility it may show under ordinary strains, it will generally give way with indications of brittleness under the blow of a projectile at high velocity, and the behaviour of the $21\frac{3}{4}$-inch Schneider plate of mild steel on this occasion, when struck by only 10-inch and 11-inch projectiles, is strongly in support of this.

The complete destruction of the lower Schneider plate by a single blow from the projectile of the 100-ton gun is also very important; though, of course, it must not be overlooked that the projectile in this case did not quite perforate the target, while similar targets, protected by rolled iron plates of the same thickness, let this nature of projectile pass through. I here refer to Messrs. Brown's and M. Marrell's $21\frac{3}{4}$-inch plates (the latter was a very brittle one), not to Messrs. Cammell's, which did not get a fair hit from the 100-ton gun.

The trials also confirm the opinion long held, at any rate, by those who have been engaged upon iron fortifications in this country, that for an armour plate to give effective resistance to the wedging action of pointed projectiles, its width must bear a certain proportion to the diameter of the shot.

We now see also more clearly, perhaps, than before, that in a plate upon plate structure, much of its effectiveness depends upon a proper distance, and no more, being allowed between the several layers of armour of which it is composed. There is strong reason for believing that the intervals in the Spezzia targets were too great.

The utter collapse of the two targets, in which the chilled cast iron blocks were used as backing to rolled iron armour, condemns, at any rate, the particular mode of construction employed in them, if not the use of cast iron in any form in structures intended to stand against heavy ship's guns.

The method of holding armour by bolts screwed a short distance into the backs of the plates is not satisfactory, and this has been seen in the trial of similar plans in this country.

Whatever may be thought of the targets that were used in these trials, there can be no doubt about the 100-ton gun having proved itself a great success. As compared with our 80-ton gun, its superiority in power, if not altogether commensurate with its additional weight, is certainly considerable. With 341 lbs. of English powder, the highest charge used against the targets, it developed energy in excess, by about 1,025 foot tons, or $3\frac{1}{3}$ per cent., of the greatest amount of work that at present can be got out of our chambered gun, namely, that produced by a charge of 425 lbs., in round 2,047, at No. 41 target, as reported in the early part of this Paper; while, with the larger charge of 375 lbs., which was used in the Italian gun in practice for range, the excess amounted to 2,825 foot tons, or nearly $9\frac{1}{3}$ per cent. However, taking into account the different diameters of the projectiles, there is probably not more than a difference of $1\frac{1}{2}$ inches or 2 inches in the present powers of the two guns as regards penetration into solid armour at short range, and this is borne out by Captain English's calculations; but, of course, this estimate will require correction in the event of the powder chamber of the Italian gun being enlarged, which, so far as we know at present, is quite feasible.

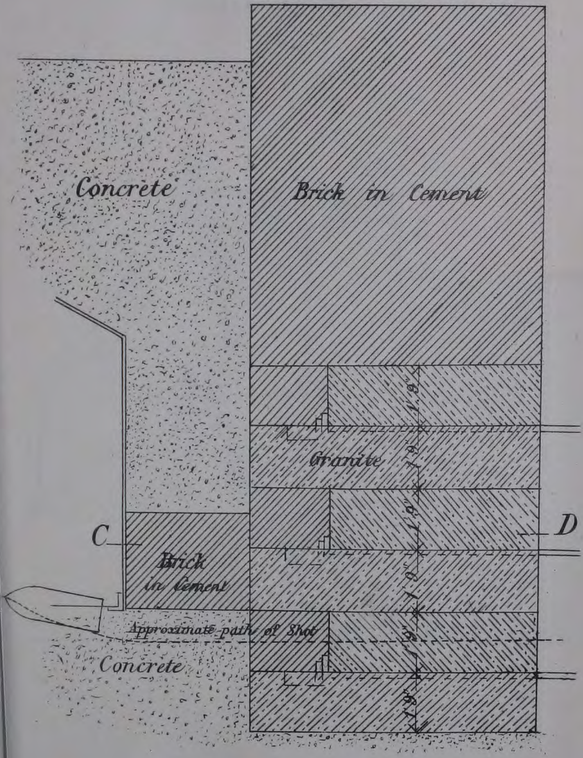
As regards accuracy of fire, it is believed that the gun has given satisfaction, and, perhaps, it should be mentioned, that the inaccuracy of two or three of the rounds against the targets was, in all probability, due to the unsteadiness of the floating pontoon on which the gun was mounted for these trials.

T. INGLIS,

June 1*st*, 1877. COLONEL, R.E.

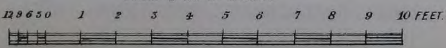
MASONRY PIER

Detail of Round 2040.



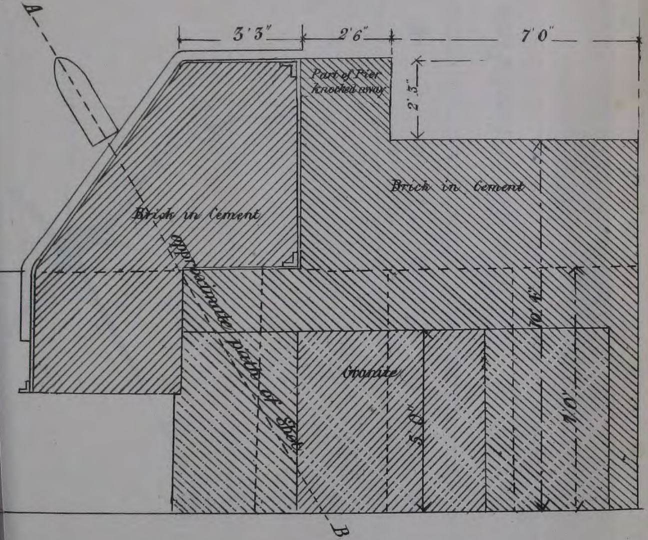
Section on line A.B.

Scale ¼ in to a foot



MASONRY PIER

Detail of Round 2040.



Plan on line C. D.

Scale ¼ in to a foot

12 9 6 3 0 1 2 3 4 5 6 7 8 9 10 FEET.

PAPER IX.

A NEW SYSTEM OF

SIGHTING ORDNANCE.

(CONTINUED).

BY CAPTAIN L. K. SCOTT, ROYAL ENGINEERS.

IN the paper on this subject published in No. 1 of the *Occasional Papers* I omitted to give a full description of the "revolving sights," which are made on exactly the same principle, and with the same object, as the telescopic sight, viz:—To dispense with all calculations in gunnery practice, and to give the artilleryman that perfect command over the axis of the piece, which he can only obtain at present by means of calculations, which, I believe, would be quite inapplicable in practice.

The only difference between the telescopic and the revolving sights is that with the former the "line of sight" is taken by means of the line of collimation of a telescope, and with the latter it is taken over the backsight and the tip of the foresight.

The revolving sight consists of a backsight and foresight rigidly connected together by means of a bar, so that when the wheels of the gun carriage are inclined, the firer, in placing the backsight in a vertical position, moves the foresight into a similar position, and thus at once, by this mechanical adjustment, dispenses with the errors due to inclined wheels.

The revolving sights are intended as a substitute for the ordinary sights in field and siege guns, but not necessarily in guns of position, which have a solid and level platform.

The telescopic sight should be used with field guns in addition to the revolving sights, whenever opportunity offers, but always with siege guns and guns of position.

The Secretary of State for War has sanctioned the trial of these sights, but no doubt a long time will elapse before their advantages are fully appreciated, because the expense of shot and shell limits the practice which is required to prove the defects of the present system.

L. K. SCOTT,

CAPTAIN, R.E.

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PAPER X.

THE MINE WARFARE.

AT SEBASTOPOL.

By Captain E. M. Lloyd, R.E.

The underground fighting at Sebastopol was not only one of the most interesting phases of the siege, and one to which the defenders look back with peculiar pride; it was also, perhaps, the most instructive example of mine warfare since the siege of Schweidnitz. But, as the English troops took no part in it, no account is given of it in the record of our engineer operations; and the Russian account was not published till 1870, when the attention of military men was directed elsewhere. As the works of General Todleben, and of General Niel are both of them bulky, and are not everywhere to be met with, an abridgement, giving an outline of the operations, will perhaps be useful to some officers of the Corps.

This may be confined to the mining in front of Bastion No. 4, known by the Allies as the Flagstaff Bastion, or Bastion du Mât, as the operations elsewhere were comparatively unimportant.

That Bastion was, in 1854, the French point of attack, and their approaches, pushed forward more rapidly here than elsewhere, were within 150 yards of the counterscarp by the 2nd of November. There they made their third parallel; but the close fire of the work now checked their further advance, and during the rest of the month they made no progress whatever.

They determined, therefore, if possible, to push forward underground, hoping " to make some heavy explosions near the Bastion du Mât, with the object of causing confusion there at the moment the assault should be given."

On the 20th November shafts were sunk behind the third parallel, and these having at length reached a layer of clay, from three to five feet thick, between two layers of rock, two galleries were started on the 11th December. They were advanced at an average rate of six feet in twenty-four hours, their finished section being four feet high, and three feet six wide. No lining was required for them, as the sides stood well, and the overlying stratum of rock formed the roof.

The Russians foresaw this mode of attack, and on their side sunk trial shafts in November to ascertain how far the soil was suitable for mining. At a depth of about 16 feet below the surface they struck the same layer of clay as the French, and at once set to work, about the middle of December, to develop a system of countermines.

Three brigades were formed, to relieve one another every eight hours, each consisting of 75 miners and 200 infantry. Shafts were sunk in the bottom of the ditch of the Bastion, at distances of about 15 yards apart; an envelope gallery was formed to connect them, and listeners were pushed out from each of them to the front. The envelope gallery was made instead of a counterscarp gallery, which, owing to the irregularity of the line of the counterscarp, and the character of the soil, would have taken much longer to execute. The galleries were at first made three feet high, and two feet six inches wide, except when lining was necessary, as it was found to be in some parts; but they were afterwards enlarged near the shafts to assist the ventilation. This was a point that presented great difficulties as the listeners advanced, as the garrison had no good machines for the purpose. Transverse galleries were found to be the most effectual measure, and were largely used. Candles could not be burned at a distance of more than from 30 to 40 yards from the shafts, according to the weather and the number of workmen; all work beyond that distance had to be done in darkness, and daily suspended for some hours, so that not more than two or three feet of advance could be made each day.

Great pains was taken to teach the miners to catch the sound of other work going on, and to judge of its position. Four times a day work was stopped in all the galleries at once for about a quarter of an hour, that the enemy might be listened for; and it was then resumed successively in the several branches, so that the men might learn to distinguish the differences of sound according to the distance, and the tools used.

At about 30 yards the pick gave a dull indistinct sound at intervals; at something under 15 yards this became distinct and more continuous. Muffled work, or loading mines, could not be heard at more than $7\frac{1}{2}$ yards.

The extent of the countermines in the beginning of February is shown on *Plate* I.; the most advanced listeners—those near the salient—were about 50 yards long.

Meanwhile two shafts were being slowly sunk through the underlying rock, to ascertain if there were any lower stratum of clay of which the enemy might be taking advantage. Owing to the hardness of the rock two months' work only carried these down seven feet.

Information from a deserter gave the defenders reason to believe that the French were advancing upon the capital of the Bastion, in the same layer as the countermines; and this was confirmed by a plan of the siege, lithographed in Paris, which had been sent to them from St. Petersburg. Accordingly the listeners near the salient were pushed forward, and at the head of one of these, on the 30th January, the enemy's miner was at length heard at work. Next day he was near enough for the sounds of his tools and the creaking of his trucks to be distinguished. A chamber was therefore formed, and the mine was loaded and tamped. The line of least resistance was estimated at 18 feet, and the charge used was 435 lbs.; for Colonel Todleben had satisfied himself, by experiments he had made at St. Petersburg, that comparatively large charges might be used at slight depths, if the enemy were allowed to approach to within a distance less than the line of least resistance, so that the explosion might take its main effect along his gallery, and not upon the surface.

The rock layers were favourable to this lateral action; and to provide for it a length of 18 yards of the branch was solidly tamped with timber and sand bags.

The French were working unsuspiciously forward, hoping to take their enemy altogether by surprise. Their right gallery had advanced 120 yards, when, at 9 p.m. on the 3rd February, its progress was stopped, and the two leading miners were killed by the explosion of the Russian mine. The effect of this quite corresponded to the expectation of Colonel Todleben. A shallow crater was formed, which, when afterwards explored, was found to be about 14 yards long, $9\frac{1}{2}$ wide, and $2\frac{1}{2}$ feet deep; but the sound, as heard by the defenders, ran away towards the parallel, and flame and smoke were seen to issue thence. There was also a crack on the surface of the ground from the crater towards the parallel upon the line of the capital of the bastion. All this showed that, as was actually the case, the French had been advancing on this line, and that the mine had taken effect along their gallery.

The Russians at once set to work to remove their tamping, in order to push forward to meet the besiegers; but after removing half of it, the rest was found to be so solidly wedged that it was easier to make a new branch alongside. They had not gone far however, when, on February 7th, the French fired a mine (F 1) too far off to injure the countermines, but showing that they were abandoning and blocking the more advanced part of their own gallery.

The French had, in fact, changed their plan of operations; and as soon as they found that there was no hope of surprising the besieged, it was decided to withdraw out of his immediate reach, and to push out branches right and left of the galleries to feel for him. By means of these a line of large craters was to be opened, in which a lodgment might be made half-way between the parallel and the counterscarp; and other mines were to be placed on the flanks to assist the making of communications from the parallel to the lodgment.

It was not thought worth while to dispute with the Russians, supported as they were by their artillery, the possession of isolated craters unable to hold strong guards, for the rocky soil made it difficult to establish good communications with them, and they lay nearer to the ditch than to the parallel. Accordingly the Russians occupied without hindrance the crater of the French mine; and sinking a 'Boule' shaft* 12 feet deep, they fired a charge of 325 lbs., which made a new crater 9 feet deep (R 2). In this they sunk a new shaft to serve as a listener, and waited for the besieger. Meanwhile their miners, working with difficulty through the ground shattered by their first explosion—where large fragments of rock had to be broken up, and removed piece by piece,—had, by the 21st February, made their way into the gallery abandoned by the French, and held nearly 30 yards of it. They found it impossible, however, to work onward within the radius of rupture of the French mine, but branched out to right and to left.

On the 26th the besiegers had fired a camouflet insufficiently tamped, without much effect (F 2); and on the 1st March they were heard at work, not only by the men established in the crater, but also in the listeners on the right and left faces of the bastion.

* A shaft lined with cases at intervals, for the rapid establishment of mines to be fired usually untamped.

It seemed that they were closing in on different sides at once. Three 'Boule' shaft mines were successively made and fired (R 3, 6, 8) from the crater lodgment, and three others (R 4, 5, 7) at the ends of three of the listeners. From these latter points the besiegers were actually at this time more than 70 yards distant, but the judgment of the miners was sometimes completely deceived by fissures in the rock. Other mines (R 9–12) were fired at the extremities of the branches run out from the captured gallery, as they were judged to be within good reach of the enemy. But before the last of these was ready the besiegers anticipated the besieged, and on April 7th fired a camouflet (F 3) which destroyed 13 yards of the branch, killed three men, and wounded two. This was the first loss the besieged had incurred in the mine warfare. "To efface the unfavourable impression which had been made on the soldiers by this explosion, Colonel Todleben caused an image of the Holy Saviour to be placed in the branch, and took energetic measures to deal the enemy on this same spot a blow equally severe." Five days later a mine (R 12) was fired here, having a charge of 780 lbs., and making a crater nearly 12 yards in diameter and 5 feet deep.

The Russians had expected that after the explosion of their first mine, which destroyed only about 4½ yards of the French gallery, the French would at once push forward and fire an overcharged mine to destroy the countermines, and to form a crater in which they might establish themselves within 20 yards of the counterscarp. On their side they were prepared to dispute the possession of any such crater. But when they found that the besieger had abandoned 30 yards of his gallery, and week after week made no sign, they became apprehensive that he might have sunk to a lower stratum, and might be undermining their whole system of countermines, and even the bastion itself. They pressed on the two trial shafts already begun, and started six others, and after passing through 22 feet of rock they came in the early part of April upon another layer of clay, from 4 to 5 feet thick, and 42 feet below the surface of the ground. They at once began to form envelope galleries and to run out listeners in this layer, although by that time their fears as to the enemy's possible progress had been allayed, as they could hear nothing of him.

Above ground the besiegers' fire along the ditches of the bastion greatly embarrassed the mining parties, destroying the blindages which had been made over the mouths of the shafts, and making the removal of the excavated earth a work of great danger and difficulty. At the same time the imminence of an assault made it unsafe to allow any accumulations in the ditch, which would interfere with its flank defence.

On the 8th April the second bombardment began, lasting ten days; and under cover of it the French endeavoured to push forward saps from the right and left of their parallel. Deserters at this time assured the garrison that the whole bastion was mined, and was to be blown up and stormed; and Colonel Todleben had great difficulty in subduing the panic excited by this news, and in satisfying the troops that the besiegers' overcharged mines, so long looked for, and now no doubt ready, must be quite out of reach of the bastion.

The French meanwhile had seen, by the increasing extent of the yellow clay deposits on the counterscarp, how considerable were the preparations made to meet them underground. They heard the Russians at work all along the front, and thought it best to remain on the defensive, with mines and camouflets loaded and tamped. They multiplied their branches, which by the 10th April numbered 36; and on the 11th they began to place charges for simultaneous explosion in 21 of these, viz. :—

6 of 4,180 lbs. each.
11 of 2,508 „
4 of 1,254 „

The four small charges were on the flanks to assist the formation of communications from the parallel, which it had been found very difficult to push forward under the fire of the bastion. To save time empty spaces were left behind the charges, and the branches were only partially tamped.

On the 15th April the mines were fired. Six of them failed to ignite, their fuzes being probably extinguished by the earliest explosions. The remaining fifteen (F 4–18) formed two very large craters* half-way between the parallel and the counterscarp, with pairs of smaller craters on either flank (see *Plate* II). The craters previously existing were almost entirely filled up. Little injury was done to the countermines, and only two men were killed in them; but in the bastion, and in the crater lodgment 30 men were killed, and 70 wounded by the stones thrown out. The French at once occupied the new craters with two companies, which were withdrawn at daybreak.

* Three, according to the Russians: they maintain that mines 6–13 did not form one continuous crater.

The Russians now assumed that the French, if they did not at once assault the bastion, would establish themselves firmly, and run out galleries from the craters for another row of mines. To hinder this, a continual fire from mortars was kept up on the craters, the countermines were pushed forward under them, and every effort was made to prevent the completion of the communications to them from the parallel. For some days the French made little progress The rocky ground made it impossible to dig deep, so that the parapets had to be formed with gabions and sand-bags; and what was done in the night was usually destroyed next day by the fire of the Russians. But the besiegers' fire concentrated upon the bastion was so crushing, that by the 20th every gun was silenced, and on that night the sap was carried from the right of the parallel to the craters. These were soon afterwards connected and extended by firing five of the overcharged mines that had failed on the 15th (F 19–23), and two new ones (F 25 and 26). As it was found that the guard of the trenches, if they were placed in the craters themselves, suffered greatly from the mortar fire, a lodgment was made for them, early in May, behind the rearward rim, where they were much less exposed either to shells or mines, and where the craters formed a deep ditch along their front, giving them security against sorties.

Little progress, however, was made towards the bastion. In the mass of shattered rock forming the side of the craters the French found it impossible to strike afresh the layer of clay, and to push forward galleries. They confined themselves to holding their ground, and keeping the Russians in check, either by using the galleries already made, or by 'Boule' shafts, sunk and loaded hastily, wherever they were found to be advancing. "If we are in possession of one of the slopes the enemy remains pretty well master of the other," is the remark in the French journal at this time. For more than two months the combat continued in this way between miner and counterminer, without marked advantage on either side, and without much loss of life. The besieged fired thirty mines, averaging nearly 300 lbs. of powder; the besiegers thirty-three mines, averaging 600 lbs. The latter also fired several stone fougasses; and in tamping their shafts they took care to use sand-bags on their own side, and stones on the side of the bastion.

During this time the French extended their lodgment, making it their fourth parallel, and connecting it with the third parallel on the left as well as on the right. The Russians made additional branches, and prolonged or repaired their old ones; and made transverse galleries for better ventilation. They also steadily continued their lower system of countermines. The French, for their part, had sunk trial shafts with a view to mining in a lower stratum, but abandoned them when they found how deep it would be necessary to go, because of the very large charges that this depth would demand.

On the 28th June two more overcharged mines (F 59, 60) were fired, one extending the existing craters to the right, and the other forming a new and more advanced crater upon the left (*Plate* III.) This evidence of an intention to work round on the flanks led the besieged at once to push forward and multiply their branches in these directions. But no advance was made from the new craters.

Everywhere the besiegers found themselves beset by the heads of the countermines, which in the centre even threatened the new parallel. To keep them in check five overcharged mines (F 75, 76, 78, 94 and 97) were fired in the old craters in the latter part of July and August. At the instance of officers, who had newly joined the mine attacks, it was determined, at the end of August, to run forward galleries from the craters of Nos. 94 and 97, which were favourable for this, as they were deep, and the clay bed was uncovered. But three days afterwards one of these galleries was completely destroyed by a countermine (R 77), and four men, who were in it, were only got out after an hour and a half's work. The other gallery was, therefore, discontinued.

Another mode of attack, however, was by this time giving promise of success. By means of successive 'Boule' shaft mines, two approaches, converging upon the capital, were gradually advancing, and threatened to cut in two the central galleries of the countermine system. The besieged found themselves unable to arrest these approaches, as the shaken soil, which would now hardly stand without support, delayed their work, and their wires frequently failed. By making additional passages they held on as long as possible to their network of advanced branches; but by the 4th September the two approaches were only separated by about 7 yards, and one well placed mine would have cut the last communication (*Plate* IV.)

By this time the most advanced branch of the lower system of countermines was within 20 yards of the 4th parallel (*Plate* V.), and it was determined to fire a heavy mine here. The line of least resistance was reckoned at 31 feet to the bottom of the crater, which was itself 15 feet deep, and a charge of 4,325 lbs. was lodged. It was assumed that this would produce a one-and-a-half lined crater, into which most of the rock thrown out would find its way back again. The sudden disclosure of this lower system of countermines was expected to have a great moral effect on the besieger; and even if he should at once set to work to encounter them by sinking to the same stratum, a long delay might be confidently reckoned on. However, the capture of the Malakhow on the 8th September, and the consequent withdrawal of the Russians to the north side of the harbour, cut short at this stage the mining operations.

General Todleben, who is justly proud of his success in holding the besieger for so many months in check, at a point where his progress was at first so rapid and so threatening, draws particular attention to the small expenditure of men and material by which this was effected, and to the marked contrast in this respect between mines and artillery defence. The actual loss of the garrison by the mine warfare was 191, but of these only 24 were killed and 32 wounded in the mines themselves; the rest were struck in the bastion or its ditch. The French give their losses as only 4 killed in the mines, and 5 killed and 36 wounded by explosions in the craters. Many others were temporarily buried, or were suffocated while untamping. The powder used in the mines by the besieged was only one-half per cent. of that used by their artillery; and even in the case of the besiegers, it was only one-and-a-half per cent.

The Russian mines were fired by electricity. Out of ninety-four explosions only one failed by neglect, but in eight cases the wires had been broken by the besieger's explosions. The French used the Larivière fuse * with the Bickford fuze. The usual rate of advance in the countermine branches was between 5 and 10 feet in 24 hours, according to the distance from the shaft. In the lower tier it never exceeded $2\frac{1}{2}$ feet. Where lining was found necessary cases were commonly used.

It was found sufficient to allow about 3 yards of tamping for every cwt. of charge, or about 1 inch per lb. Where an explosion was feared before a branch could be loaded, it was tamped without loading.

General Niel has found fault with the extreme irregularity of the countermine branches, which, from the time they encountered

* Quick match, protected by a waterproof envelope, and burning at the rate of 100 mètres a second.

the enemy, would seem to have been carried on almost without plan, as if each leading miner took his own line. Hence there was a much greater extent of branch than was required by the number of heads of attack; it must often have been impossible for the miners to distinguish between the sounds of their enemy's work and that of their neighbours; and any considerable explosion directed against the enemy was sure to injure some gallery of their own.

General Todleben replies to this criticism that such irregularity necessarily follows from the obligation to direct the branches from day to day according to the sounds of the enemy's workmen, and the mines he fires. This branch must be pushed forward; from that branch we must break out to the right; another, perhaps, has been destroyed, and a substitute must be made for it. Nor, as a matter of fact, were the inconveniences experienced, which, it is assumed, must result from this.

The lower system of countermines, in General Niel's opinion, involved more labour than the strength of the enceinte warranted. It was carrying too far the maxim, that "dans les mines celui qui a le dessous a le dessus." The mine of this system that was actually found loaded would have had little effect; for though it was unsuspected, yet, on account of the mines of the upper system, the French had no intention of massing troops in the craters. But General Todleben points out that this lower system would have allowed of the destruction of all the French galleries in the upper layer; it gave confidence to the miners in that layer; and if the besieged had neglected, and the besiegers had taken advantage of, this lower stratum, the whole of the countermine system and the bastion itself might have been destroyed.

The main conclusions to be drawn from the mine warfare at Sebastopol are thus summed up by General Todleben.

Attack.

"The besieger should advance by several galleries, taking care to secure those on the flanks by listeners. He must, however, be energetic and persistent in his attack, for the defence will turn every moment's delay to account in the development of his system of countermines, so as to arrange an attack by a superior number of listeners.

"Once within the sphere of the enemy's mines, the besieger, when he receives the first camouflets, must in no way slacken his advance even though some of his branches may have been struck.

"On the contrary, this is the very time that he must make every exertion to fire his overcharged mines in the galleries that are still uninjured, in order to destroy the countermines and so bar the way to the besieged.

"One can rarely attain one's end in such a case without suffering loss more or less heavy; but too much prudence and circumspection for the sake of avoiding loss will almost always result in complete failure for the besieger.

"Before firing the overcharged mines the besieger must have everything in readiness:—

"1. For occupying and intrenching himself in the craters immediately afterwards.

"2. For forming an open communication from the trenches to the craters by means of the sap, helped by intermediate explosions simultaneous with the overcharged mines.

"3. For constructing a certain number of shelters for the guards told off to protect the craters against sorties. For this purpose the French arrangement, before No. 4 bastion, of a parallel behind the rim of the crater may be recommended.

"After having occupied the craters, the besieger should push on from them at once with his galleries,—usually straight forward to continue the attack, but sometimes also laterally to secure the flanks and to connect the craters by mines between them.

"The galleries of attack must be long enough to allow of a tamping corresponding to the charges. If by any accident this cannot be complied with, heavier charges must be used to make up for the shortness of the galleries. The besieger should only use camouflets in exceptional cases, or when the counterminer is so close that he has no time for an overcharged mine. Even in this case the besieger should do his best to make his charge heavy.

"Supposing the besieged has anticipated the besieger, and has managed to surround the craters by a large number of branches, the besieger must then endeavour to sink below the countermines, or destroy them by 'Boule' shafts made in the surface strata. Moreover, if the fire of the place should be so violent as to make it alike impossible to establish a lodgment and to sink a shaft deep enough for a considerable charge, the besieger must begin with shallower shafts and small charges, so as first of all to break through the obstacles which the most advanced countermines present to him.

"After having fired these and occupied their craters, he must sink deeper shafts in those craters, and fire overcharged mines in them;

then he will at once occupy the new craters so made, and connect them with those already existing, and so continue resolutely to advance, employing such of the methods we have mentioned as may best suit his circumstances.

Defence.

"The besieged should push out his countermines as far as possible beyond the crest of the glacis, and secure them against attack from below, down to whatever depth the enemy can be supposed to be advancing at. To connect the galleries by transversals is the most effective means of ventilating them, and these transversals should form salient angles towards the country. A series of transversals so made will constitute an envelope gallery of indented trace. With the same object it will be useful to bore holes in the galleries up to the surface of the ground.

"Suspending work several times a day, the besieged should listen attentively to discover the work of the attack in good time. Having caught in one of the branches the sound of the enemy's miner, the counterminer should continue to advance towards it, working noiselessly, or else at once form a mine chamber and load it, and then wait, listening at the point where the fuse trough comes through the tamping, until the enemy is near enough. At all other points, where the enemy is not yet to be heard, the besieged should continue their work vigorously.

"The true judgment of distance by carefully listening to the enemy's workman is a point of the utmost importance in mine warfare, and therefore the miners should be thoroughly practised at it. Miners inexperienced in such warfare are usually apt to under-estimate the distance of the enemy. Frequently this want of practice added to the excitement and interest which the miners feel more and more as they approach the enemy, leads to premature explosions, or to misfires. To accustom officers as well as men to look at matters calmly and coolly, they should be made to understand, in the work of the practice-ground, that it is much better to come into actual collision with the enemy's miner than to produce an explosion without being satisfied that the enemy's distance is less than the length of the line of least resistance.

"With the same object it is well to take care that, during the establishment of the countermine system, the miners pay attention to the sounds of work in the galleries adjacent to them, and especially in the portions of transversals which are advancing towards each other; and the distances so estimated by the ear should be carefully verified by the working plan.

"The two leading considerations for the besieged are:—

"1. To endeavour to destroy the enemy's galleries as extensively as possible.

"2. To avoid making craters of any considerable depth on the surface of the ground.

"Consequently the besieged should establish his countermines at such depths that even if he uses large charges they may not produce craters. And to destroy the greatest possible length of the besieger's galleries the besieged should not fire his mines until the enemy's distance from him is less than the line of least resistance.

"In that case he may, without fear of making too deep craters, increase his charges up to one-and-a-half times, or even twice, the charge of a camouflet, reckoned as the charge for a common mine, but taking only four-sevenths* of the line of least resistance; for the charge will produce most of its effect in the enemy's gallery, and its action on the surface will be insignificant. It is only when the ground has been much shaken by previous explosions that a smaller charge must be used.

"Besides, even if a shallow crater is made, the besieged may occupy it, if circumstances are in their favour, taking care to cut away its slope on the side of the fortress sufficiently to allow their artillery to search the interior of it. Or if the besieged should not succeed in getting possession of the crater, or, having made a lodgment, should be driven out of it, it will be a very difficult matter for the besieger to hold his ground there, so close to the works of the place; for, so long as the place can still mount any artillery, the crater will always serve as their target.

"Throughout the mine warfare the besieged should avoid premature explosions, to which he will be tempted by a fear that the attack will anticipate him. Repeated instances, alike in war and in peace, make it quite certain that such apprehensions have always been unfounded. The miner who acts with coolness and wise circumspection will never have reason to repent it.

"This is proved by the fact that the counterminer who fires a mine when the distance of the enemy's gallery is greater than the line of least resistance, succeeds only in damaging his own branch, and making a crater, without doing any serious harm to the

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* One-half, according to the English rule.

besieger. So that the besieged is actually in a worse position than he was before he fired his mine; for, obliged to fall back several yards, he will leave the besieger free to prepare an overcharged mine, or to sink a 'Boule' shaft in the crater he has made.

"After two or three successive explosions in the same branch, much of it will necessarily be injured. On this account, and in order not to be driven back at this point, it is well for the besieged to provide himself, while there is yet time, with a reserve branch, placed at a small distance from the injured branch.

"After the besieger has fired his overcharged mines the besieged should:—

"1. Hinder the enemy from occupying the craters, by a violent fire of grape and musketry. But if he nevertheless takes possession of them, a continuous fire from mortars must be directed on the craters; while by the fire of guns the making of any communication above ground should be stopped, so as to prevent the assailant from solidly establishing himself in the craters, and resuming his mines.

"2. Push forward at once by his branches, introducing himself under the actual slope of the craters, and embracing them in front and on the flanks.

"The branches must be disposed at minimum intervals apart, so that the besieger may not be able to pass between them without receiving a camouflet.

"3. Produce explosions inside the craters, supposing that the besieged has been successful in arresting every attempt of the besieger to open new galleries in the bottom of the craters.

"'Boule' shafts being very dangerous for the countermines, the besieged should do his best to oppose their formation, above ground by artillery and musketry fire, and underground by camouflets, striking the besieger through holes bored for that purpose. Further, he must take advantage of every favourable opportunity to delay the progress of the siege works by sorties from the place.

"Such are the principal rules to be drawn from the practice acquired during the siege of Sebastopol, and during previous sieges. The observance of these rules is a necessary condition to secure a favorable issue in a war of mines. At the same time it is to be remarked that each particular case may present exceptional circumstances, and that success in mine warfare will always depend, not only on the observance of these general rules, but also, and even more, on the miner's power of weighing all such circumstances, and his skill in turning them to the best account."

E. M. L.

EXPLOSIONS.

Date.		Russian. No.	Russian. Pounds.		French. No.	French. Pounds.
February 3rd	...	1	433	...	—	—
„ 7th	...	—	—	...	1	407
„ 9th	...	2	324	...	—	—
„ 26th	...	—	—	...	2	154
March 2nd	...	3	108	...	—	—
„ 3rd	...	4	433	...	—	—
„ „	...	5	541	...	—	—
„ 5th	...	6	541	...	—	—
„ „	...	7	541	...	—	—
„ 7th	...	8	433	...	—	—
„ 10th	...	9	433	...	—	—
„ 15th	...	10	433	...	—	—
„ 23rd	...	11	433	...	—	—
April 7th	...	—	—	...	3	198
„ 12th	...	12	757	...	—	—
„ 15th	...	—	—	...	4	1,254
„ „	...	—	—	...	5	1,254
„ „	...	—	—	...	6	2,508
„ „	...	—	—	...	7	2,508
„ „	...	—	—	...	8	2,508
„ „	...	—	—	...	9	2,508
„ „	...	—	—	...	10	2,508
„ „	...	—	—	...	11	4,180
„ „	...	—	—	...	12	4,180
„ „	...	—	—	...	13	4,180
„ „	...	—	—	...	14	4,180
„ „	...	—	—	...	15	2,508
„ „	...	—	—	...	16	2,508
„ „	...	—	—	...	17	1,254
„ „	...	—	—	...	18	1,254
„ 22nd	...	—	—	...	19	4,180
„ „	.	—	—	...	20	2,508
„ 23rd	...	—	—	...	21	4,180
„ „	...	—	—	...	22	2,508
„ „	...	—	—	...	23	2,508
„ 24th	...	13	433	...	—	—
„ „	...	14	433	...	—	—
„ „	...	15	433	...	—	—

Date.		Russian. No.	Russian. Pounds.		French. No.	French. Pounds.
April 25th	...	16	433	...	—	—
„ 28th	...	—	—	...	24	418
„ 30th	...	17	324	...	—	—
„ „	...	18	433	...	—	—
May 1st	...	19	433	...	—	—
„ „	...	20	324	...	—	—
„ „	...	21	324	...	—	—
„ „	...	22	433	...	—	—
„ „	...	23	324	...	—	—
„ 2nd	...	24	324	...	—	—
„ „	...	25	433	...	—	—
„ 3rd	...	—	—	...	25	1,672
„ „	...	—	—	...	26	2,508
„ 12th	...	—	—	...	27	836
„ 14th	...	26	216	...	28	418
„ 15th	...	—	—	...	29	460
„ „	...	27	216	...	30	836
„ 16th	...	28	216	...	31	836
„ 17th	...	—	—	...	32	836
„ 18th	...	29	324	...	—	—
„ „	...	30	216	...	—	—
„ 19th	...	—	—	...	33	836
„ „	...	—	—	...	34	836
„ 24th	..	—	—	...	35	418
„ 27th	...	31	216	...	36	585
„ „	...	—	—	...	37	877
„ 28th	...	32	216	...	38	125
„ „	...	—	—	...	39	627
„ 31st	...	—	—	...	40	836
„ „	...	—	—	...	41	418
„ „	...	—	—	...	42	418
June 3rd	...	—	—	...	43	418
„ „	...	—	—	...	44	594
„ 4th	...	33	216	...	45	418
„ „	...	34	216	...	—	—
„ 5th	...	35	216	...	46	752
„ „	...	—	—	...	47	836
„ „	...	—	—	...	48	502
„ 6th	...	36	216	..	—	—

Date.	Russian. No.	Russian. Pounds.	French. No.	French. Pounds.
June 9th	—	—	49	836
,, 11th	—	—	50	669
,, 12th	—	—	51	460
,, 13th	37	108	—	—
,, 15th	—	—	52	460
,, 19th	—	—	53	627
,, 20th	—	—	54	627
,, 21st	38	216	—	—
,, ,,	39	108	—	—
,, 22nd	—	—	55	418
,, ,,	—	—	56	460
,, 24th	40	216	57	1,087
,, 25th	41	216	—	—
,, 26th	42	216	58	502
,, 28th	—	—	59	2,508
,, ,,	—	—	60	2,508
,, 29th	—	—	61	1,254
July 7th	43	216	—	—
,, 8th	—	—	62	627
,, 10th	44	216	—	—
,, 11th	45	216	—	—
,, 12th	46	216	—	—
,, ,,	47	216	—	—
,, 14th	—	—	63	634
,, ,,	—	—	64	634
,, 15th	—	—	65	634
,, 16th	48	216	66	502
,, 17th	49	216	—	—
,, 18th	—	—	67	334
,, ,,	—	—	68	334
,, 20th	—	—	69	836
,, 21st	—	—	70	627
,, 22nd	50	108	71	627
,, ,,	—	—	72	627
,, 24th	—	—	73	627
,, 26th	51	216	—	—
,, 27th	—	—	74	627
,, 28th	52	216	—	—
,, 29th	—	—	75	2,800

Date.		Russian. No.	Russian. Pounds.		French. No.	French. Pounds.
July 29th	...	—	—	...	76	2,926
„ 30th	...	—	—	...	77	1,086
„ 31st	...	53	216	...	—	—
August 1st	...	54	216	...	—	—
„ 2nd	...	—	—	...	78	2,508
„ „	...	—	—	..	79	836
„ „	...	—	—	...	80	418
„ 3rd	...	55	216	...	—	—
„ „	...	56	108	...	81	502
„ 4th	...	57	108	...	—	—
„ 5th	...	58	108	...	—	—
„ 7th	...	59	216	...	—	—
„ 8th	...	60	216	...	82	627
„ „	...	—	—	...	83	627
„ 9th	...	61	216	...	84	627
„ 11th	...	—	—	...	85	585
„ „	...	—	—	...	86	585
„ 12th	...	—	—	...	87	627
„ „	...	—	—	...	88	502
„ 13th	...	—	—	...	89	836
„ 14th	...	62	216	...	90	627
„ „	...	63	216	...	—	—
„ 15th	...	64	432	...	91	752
„ „	...	65	216	...	92	752
„ 16th	...	—	—	...	93	502
„ 18th	...	66	216	...	—	—
„ 20th	...	—	—	...	94	2,508
„ 21st	...	67	432	...	—	—
„ 22nd	...	68	216	...	—	—
„ 23rd	...	69	216	...	—	—
„ 24th	...	70	324	...	—	—
„ „	...	71	324	...	—	—
„ 25th	...	—	—	...	95	836
„ „	...	—	—	...	96	627
„ 26th	...	—	—	...	97	2,090
„ 27th	...	72	253	...	98	627
„ „	...	73	324	...	—	—
„ „	...	74	324	...	—	—
„ 28th	...	75	216	...	—	—

Date.		Russian. No.	Russian. Pounds.		French. No.	French. Pounds.
August 28th	...	76	180	...	—	—
„ 30th	...	77	216	...	—	—
„ „	...	78	180	...	—	—
September 1st	...	79	108	...	—	—
„ 2nd	...	—	—	...	99	627
„ „	...	—	—	...	100	1,254
„ „	...	—	—	...	101	1,254
„ 3rd	...	80	216	...	102	1,254
„ „	...	—	—	...	103	1,045
„ „	...	—	—	...	104	1,045
„ 4th	...	81	108	...	106	1,254
„ „	...	82	216	...	107	1,626
„ 5th	...	83	216	...	—	—
			23,095			131,734

N.B.—The above table is taken from the Russian account. There are some discrepancies between that and the French account as regards the number of the Russian explosions.

PAPER XI.

A BRIEF SKETCH OF THE PRESENT STATE

OF

BRITISH GUNNERY.

BY MAJOR EARDLEY MAITLAND, R.A.

A Lecture delivered at the R.E. Institute, on 31st July, 1877,

THE last three or four years have witnessed remarkable progress in the science of Artillery, not only in our own country, but among nearly all the continental nations, and it would be quite impossible to convey to an ordinary audience in one short lecture any adequate idea of the advance which has taken place all along the line. Fortunately, those now present have already been thoroughly grounded in the subject of gunnery, and I will therefore assume that all are conversant with general principles, and if in the endeavour to compress, and to avoid unnecessary detail, I become obscure, perhaps I may be kindly permitted to answer any questions that you may wish to put after the lecture is over.

As time is short I omit all reference to the old smooth bored ordnance, and plunge at once into the subject of rifled guns, dividing it into two parts:—

1st. The guns we could bring against the enemy if we were to go to war to morrow.

2nd. The guns we hope to introduce into the service as soon as preliminary experiments are brought to a close.

I have prepared two tables giving certain particulars of the weights, power, and employment of the rifled ordnance in our services. Table A includes all the principal guns in the land service. Table B shows those in the sea service.

It has always been an object with the authorities to assimilate the guns of the two services as far as their respective requirements will permit, and so to avoid multiplication of stores at the numerous home and foreign stations where supplies are made; but still it will be observed that considerable differences exist, and judging from the progress of events, it appears that these differences will increase, because as the science of gunnery becomes developed, each new kind of gun is more exactly fitted to the performance of the special work for which it is intended, and therefore less suitable for other purposes; as an illustration of my meaning the history of the muzzle loading 9-pr. of 8 cwt., may be adduced; this gun was originally intended for, and issued to, the Horse Artillery and field batteries, and was a few years ago the most powerful piece of its size in the world; thereupon the navy adopted it as a boat gun. Improvements were made; other nations found it possible to obtain equal power with lighter guns. Our field 8 cwt. gun was replaced by a 9-pr. 6 cwt. gun using precisely the same ammunition; all the land service 8 cwt. 9-prs were practically superseded; the recoil of the lighter gun was of course considerably more violent than that of the heavier, but the field carriages were improved and strengthened so as to obviate the difficulty arising from this cause; with the boats the case was different, the recoil proved objectionable, and as the additional weight of two cwt. is of much less consequence in a boat than behind a team of horses, it was determined to use all the land service 9-prs. of 8 cwt. for boats. Thereupon the land service discovered that though 6 cwt. was perhaps better than 8 cwt. for Horse Artillery, yet that if a considerable increase of power could be obtained by adding the two cwt., the field batteries could well manage to draw it; and accordingly a 12-pr. of 8 cwt. was designed, and is now in process of introduction; I shall describe it farther on, and will only say now that it is by far the most powerful weapon in the world of its kind. This short history shows that the theory of evolution in a Darwinian sense applies to guns as well as to organic beings.

Table A shows five distinct classes of rifled ordnance; we will take them in order.

You have all seen the several ways in which the *heavy armour piercing guns* are mounted round our coasts, and as you construct

TABLE A. *LAND SERVICE RIFLED GUNS.* *July, 1877.*

Nature, Weight, Calibre, &c.	Weight of heaviest Projectile.	Max. Service Muzzle Velocity.	Class.	Perforation at 1,000 yds. About	Bursting charge of com. shell—about	How Mounted.	Remarks.
Muzzle Loading.	lb.	f.s.		ins.	lb. oz.		
12″·5 of 38 tons.	800	1420	Armour piercing guns.	..............16·0..............	50 0	In casemates, on sliding carriage on traversing platform on racers.	Experiments still in progress.
12″·0 of 35 tons.	700	1340		..............13·7..............	40 0	Barbette only on ditto ditto.	Very few of these guns exist. Common shell 618. lb.
12″·0 of 25 tons.	600	1300		..............10·8..............	38 0	In casemates on do., and en barbette.	Ditto. Com. shell 495 lb.
11″·0 of 25 tons.	535	1315		..............11·9..............	30 0	Do. Do. Do.	Experiments still in progress.
10″·0 of 18 tons.	400	1365		..............11·2..............	20 0	Do. Do. Do.	
9″·0 of 12 tons.	250	1420		.... 8·8..............	19 0	Do. Do. Do.	
7″·0 of 7 tons.	115	1560	Land front (fortress) guns.	Armour piercing projectiles not supplied for these and smaller guns.	9 0	En barbette, sliding carriages on traversing platfrm. Moncrieff carriages.	Double shell, 160 lb.
7″·0 of 82 cwt., breech loading.	90	1165			6 0	Do. Do.	
80-pr. (6″·3) 5 tons.	80	1240			9 0	Sliding carrs. on traversing platform.	
64-pr. (6″·3) {71 cwt. & 58 cwt.}	64	{1230 1245			7 0	Standing and Moncrieff carriages.	Converted from 8″ s.b. gun and 32 pr. s.b. gun.
64-pr. (6″·3) 64 cwt.*	90	1365	Siege Train guns.	23 to 25ft. from point of shaft to muzzle of gun.	7 0	Travelling carriages (siege).	Common shell, 64 lb.
40-pr. (4″·75) 35 cwt.	40	1360			3 0	Do. (siege & batteries of position).	
25-pr. (4″·0) 18 cwt.	25	1320			2 0	Do. Do.	
8″·0 howr. 46 cwt.	180	790			14 0	Travelling carriages (siege); also on beds for siege.	
6″·3 howr. 18 cwt.	64	830			7 0	Travelling carriages (siege).	Experiments in progress.
16-pr. (3″·6) 12 cwt.	16	1355	Field guns.	About 23ft. from point of shaft to muzzle of gun.	1 2	Field gun carriages, with limbers.	Shrapnel 18·5 lb.
9-pr. (3″·0) 6 cwt.	9	1390			0 7	Do. Do.	
7-pr. (3″·0) 200 lb.	7	970	Mountain Train guns.	....	0 6	Mountain service,—on travelling carriages. Siege,—on beds.	Double shell, 12 lb.
7-pr. (3″·0) 150 lb.	7	675		....	0 6	Do. Do.	Do.

* Special projectiles for penetrating masonry.

Nature, Weight, Calibre.	Weight of heaviest Projectile.	Max. Service Muzzle Velocity.	Perforation at 1,000 yds. About	Bursting charge of com. shell—about	How Mounted.	Remarks.
Muzzle Loading.	lb.	f. s.	ins.	lb. oz.		
12″·5 of 38 tons.	800	1420	...........16·0...........	50 0	In turrets, loading by hydraulic machinery.	Experiments still in progress.
12″·0 of 35 tons.	700	1340	...........13·7...........	40 0	In turrets, loading by hand gear.	Very few of these guns exist. Common shell, 618 lbs.
12″·0 of 25 tons.	600	1300	...........10·8...........	38 0	Do. do., and broadside.	Very few of these guns exist. Common shell, 495 lbs.
11″·0 of 25 tons.	535	1315	...........11·9...........	30 0	Broadside, revolving, and on turntable *en barbette.*	Just introduced for Navy. Experiments in progress.
10″·0 of 18 tons.	400	1363	...........11·2...........	20 0	Broadside, revolving, in turrets, and gun-boats.	
9″·0 of 12 tons.	250	1420	.... 8.8...........	19 0	Broadside and revolving.	
8″-0 of 9 tons.	180	1415	.... 7.7...........	14 0	Broadside.	
7″·0 of 6½ tons.	115	1525	Armour piercing projectiles not used for guns of less than 8″ calibre.	9 0	Broadside.	Double shell, 160 lbs.
7″·0 of 90 cwt.	115	1525		9 0	Broadside.	Do. do. Experiments in progress.
64-pr. (6″·3) of 64 cwt.	64	1385	....	7 0	Broadside.	
64-pr. (6″·3) of 71 cwt.	64	1230	....	7 0	Broadside.	Converted from 8″smooth-bored shell gun
9-pr. (3″·0) of 8 cwt.	9	1380	....	0 7	Boat.	
9-pr. (3″·0) of 6 cwt.	9	1235	....	0 7	Boat.	
7-pr. (3″·0) of 200 lb.	7	970	....	0 6	Boat.	Double shell, 12 lbs.
Breech loading.						
20-pr. (3″·75) of 13 cwt.	21	1000	....	1 2	Gun vessel and upper decks of ironclads against torpedo vessels.	
12-pr. (3″·0) of 8 cwt.	12	1170	....	0 8	Boat—nearly obsolete.	
9-pr. (3″·0) of 6 cwt.	9	1060	....	0 6	Do.	

the casemates, barbette batteries, &c., for us, and no doubt are thoroughly familiar with the subject from an engineering point of view, I will merely mention that while the artilleryman quite appreciates the comfort of being made as safe as possible, he is also desirous of inflicting the maximum amount of damage upon the enemy. To do this it is absolutely essential that he should be able to lay his gun with accuracy and rapidity; and here he wants your help in several points. You must provide a good look-out place, more especially with the new system of firing at objects in motion unseen by the gunners. You must provide for the rapid supply of cartridges and projectiles, so that a swift steam vessel may not get past unmolested. Supposing a gun to train through an angle of 50°, and a vessel 1,000 yards off to be steaming at 12 knots, it will take barely two minutes and a half to get by. Evidently it is of the utmost importance to be able to get a second shot. Having loaded in time, in order to hit, we must have the racers true, and I trust I shall be forgiven if I make a great point of this. I know it is a matter of difficulty to lay a racer true, firm, and solid; but it really must be done if we are to make decent practice. It is not only that a depression in the racer allows one truck to sink, and so throws out the line, but, worse than this, it renders it impossible to get the gun into line at all, unless the bottom of the indent happens to be exactly in the right place. No amount of scotching up will ensure accuracy of direction if the depression is a bad one; directly the recoil begins, before the shot has left the muzzle, a shift takes place, and the aim is spoiled.

Turning to the guns with which the *land fronts* of our fortified places are armed, it will be seen that, with the exception of the 7-inch muzzle loading gun, they are all somewhat less powerful than the most effective of the siege train guns. I believe, and hope, that a proportion of 9-inch guns will, before long, be provided for our land fronts, as otherwise we certainly fail to utilize the full advantage to be derived from a position fortified and armed at leisure.

A large number of 7-inch breech-loading guns has recently been put in order, and told off to the Portsmouth forts. Most of our strong places are still armed largely with the old smooth bores, and there is no doubt that this portion of our equipment is less advanced than any other; such will necessarily be the case as long as an invasion of England is regarded as a danger of a somewhat visionary character; long may it remain so.

With regard to the *siege trains*, I must refer those specially interested in this part of my subject to the forthcoming report of the Siege Operation Committee—a report which I feel sure will deal with the various branches of the question in a comprehensive and exhaustive manner. There are, however, a few remarks which I should like to make while I have the opportunity. You see (Table A) we have in the siege train nothing heavier than 64 cwt. This is the maximum weight which it is considered can be dragged over a favourable country, while the 35 cwt. gun is intended to take the place of the heavier one when the country is unfavourable. In our old wars it was always considered that if the fortress possessed guns equal, or at any rate slightly superior to the enemy's siege train, all was done that could be done. Tradition has great vitality in the army, and we have, I think, scarcely yet learned to appreciate the enormous change which has taken place in the facilities for transport in civilized countries, nor have we yet yielded to the conviction that it is impossible to possess too powerful artillery—that a crushing superiority is the cheapest defence.

The siege train is all very well for the attack of out of the way places, but in Europe nearly every city of importance has many railroads converging on it. If these are in the hands of the besieger he can bring up guns far more powerful than 64-pounders. If we were to attack Sebastopol again now, I make no doubt that we could run up a line to carry 9″, or even 10″ guns, and place them in position; and those who build and arm fortresses must be prepared for this.

The 25-pounder guns of 18 cwt. are intended for the siege train in difficult countries, or in India. They will also, no doubt, be used as guns of position, and perhaps in time as heavy field guns. The 8″ howitzers carry a heavy shell, and are intended for use either as mortars or howitzers. They can be fired either on their travelling carriages or on the ground, as the body of the carriage, when the wheels are removed, forms a convenient bed. The 6″·3 howitzers are intended to perform similar duties.

The siege train guns are grouped into two classes. A unit of the heavy train comprises:—

64-pounders of 64 cwt.	8
40 ,, of 35 ,, ...	8
8″ howitzers of 46 ,, ...	14

A unit of the light train comprises:—

40-pounders of 35 cwt.	... ...	10
25 „ of 18 „	... ...	10
6″·3 howitzers of 18 „	... ...	10

and each unit is completed in every respect with its own stores, spare parts, repairing implements, &c.

With regard to the two natures of *field guns*, which are very much like one another except in weight, I need only remark that it is quite time that their power and range should be fully recognized. The army at large has an idea, derived from the exploits of smooth-bored artillery, that field guns cannot do much at ranges over 1,200 yards. This is a very great mistake, and the Okehampton experiments have, I think, done a good deal to correct it; indeed some enthusiastic gunners, on the strength of these trials, would vaunt the prowess of the 16 and 9-pounders as extending to 4,000 yards. Without, however, quite subscribing to this estimate, I think there is no doubt whatever that the 9-pounder will inflict much injury on troops up to 2,500 yards, and 16-pounders up to 3,000; so much so indeed that a column would scarcely be able to show itself at those distances without serious loss.

The *mountain train guns* are both 7-pounders; they fire the same shell, but the heavier one uses a 12-oz. cartridge, while 6-oz. is as much as can be fired from the lighter one. Both guns are intended for mule transport, one mule taking the gun, another the carriage: but at the Cape of Good Hope the heavier 7-pounder is mounted on a light high field carriage for transport as well as for firing, while in Ashanti the lighter 7-pounders were dragged on a kind of sleigh. The lighter gun is tolerably effective for nearly a mile, and the heavier for about a mile and a half.

Turning now to Table B, in which the principal sea service rifled guns are shown, it will be evident that there are three kinds of work to be performed by them, viz., to pierce ironclads and armoured forts; to attack unarmoured vessels; and to keep up a fire on troops on shore, or on approaching boats. The heavy armour piercing guns are well provided with common shell as well as with chilled projectiles, so as to perform the first and second duties, but they have a very small proportion of shrapnel shell, which is intended to be used by them against troops or boats only on emergency. The 7″ and 64-pounder guns are supposed to be quite sufficient in ordinary cases for the second and third duties, assisted in the third case by the smaller boat guns. All these are well furnished with common shell and shrapnel.

It might often happen that excellent service would be done by naval guns landed and placed in defence of some fortification or field work. Such employment would be merely a question of transport, as the naval carriages are, of course, not designed for locomotion, except in a few cases, where the blue-jackets are taught to land and manœuvre a regular field battery, *minus* the horses.

I have now given you a hasty outline of the kinds of guns we could bring against the enemy at once, together with a sketch of the general principles which would guide their employment on service. Progress makes, however, such rapid strides nowadays, that much of what you have on Tables A and B may shortly be altered, and in order that approaching changes may be intelligible to you, it seems desirable to make a few remarks on the character of the gunnery experiments now in progress.

With very heavy guns the chief object is to drive a projectile through the thickest armour at a fighting range.

With medium guns, shell power is the prime object.

With small guns, everything must be sacrificed to efficiency of shrapnel fire.

For heavy guns, the striking energy of the projectile must be as great as possible, as compared with the size of the hole to be made. Taking the weight of the shot of any calibre as fixed, we require then the highest attainable velocity. At the same time we have to fire very many rounds from the gun, which should be as light as is consistent with safety and manageability. Hence, briefly, we want the ratio of muzzle velocity of shot to breech pressure of gas to be as high as possible, and for some years the principal efforts of artillerists have been directed to this end. In 1869 we were obtaining with our heavy guns (10″ & 12″) muzzle velocities of about 1200 feet per second, with powder pressures at the breech measuring 40, or even 50, tons on the square inch. These pressures were local, it is true, and lasted but a very brief time; otherwise no guns could have sustained them. Still, they were highly injurious to both gun and projectile. We are now beginning to get velocities with similarly proportioned projectiles from our heaviest ordance of 1600 feet per second, while the pressures do not exceed 20 or 21 tons. Several important improvements have combined to bring about this advance. They all arise from the acquisition of a more perfect knowledge of the action of the powder gas inside a gun, and the principal ones are three in number.

First, a great stride was made in the manufacture of powder when pebbles—and subsequently $1\frac{1}{2}''$ cubes—were introduced.

Second, the discovery of the beneficial effect of *chambering*, that is, of boring out the powder chamber to a greater diameter than that of the rest of the bore.

Third, the method of adjusting the cartridge so that a certain weight of powder should have a certain definite space allotted to it, the amount being determined by experiment, and being irrespective of the actual volume of the powder grains. Thus, in the 80-ton gun, powder cubes of $1\frac{1}{2}''$ edge were used, their absolute density being a little over 1·75, or about 15·7 cubic inches per pound. When these grains were rammed tightly home in a serge bag, the space occupied behind the shot was 24·6 cubic inches per pound; as actually used for practice a vacant space over and within the cartridge was left, so that the space behind the shot amounted to 34 cubic inches per pound.

I will now describe, as well as I can, the action that takes place in the bore of a gun when the flame reaches the cartridge. It is not very easy to convey an adequate impression of it, and I must ask your patience. If I am successful in making it clear, the *rationale* of the three improvements just enumerated will become clear also, and probably you will wonder why they were not carried out long ago.

Suppose the cartridge to consist of ordinary powder grains, rammed up as tightly as they will conveniently bear (R.L.G. powder, 28 cubic inches per pound; pebble, 26; $1\frac{1}{2}''$ cubes, 24·6). and the flame to be applied to one end. And here I must remind you that gunpowder is not properly an explosive, but a substance which burns (and gives off its gas) with great rapidity. It cannot, as far as is yet known, be detonated, but simply burns down from the outside surface to the heart of the grain, which is thus gradually converted into gaseous and liquid products. We have now got to the application of flame at one end of a cartridge; the nearest grains then ignite, and their surfaces rapidly evolve gas in a state of violent incandescence. This gas travels with great velocity through the interstices between the grains composing the rest of the charge, lights them in passing, and is continually augmented in volume by their gas, the combination gaining velocity as it proceeds, till, arriving at the farther end of the cartridge, it receives a check, and applies a pressure with great suddenness; this pressure is often called a blow. It immediately reacts on the now greatly increased quantity of gas evolved behind, and, when excessive, results in those abnormal indications registered by the crusher gauges, and spoken of by artillerists as "wave pressures." These wave pressures are dynamical, and the records given by them greatly exceed those of the steady pressure given even by charges in closed vessels. I have not time to describe the instruments used to ascertain these particulars, but an excellent description of them, by Captain Jones, R.A., will be found in Vol. IX. of the "R.A. Institution Proceedings." As one illustration, I may mention that if a cartridge of quick-burning powder, rammed tightly, and having a length of about three times its thickness, be lighted at one end, and if pressure gauges be placed in the walls of the gun—one at each end of the charge, and one over the middle—those at the ends will usually register about double the pressure per square inch that will be indicated by the centre one.

I have specified a "quick burning" powder; by that term is meant a powder the grain of which is small in proportion to the calibre of the gun. All our gunpowders, from the old *poudre brutale* L.G. to the large cubical $1\frac{1}{2}''$ powders of the present day, are made of the same ingredients combined in the same proportions, they vary only in density and in size of grain. Turning back for a moment to the action of the lighted gas evolved from the first ignited grains, and rushing through the cartridge, lighting up all the grain surfaces it meets with, it becomes at once evident that the larger the grains of powder are the less will be the surface thus lighted up; of course, if you take a cube of $1\frac{1}{2}''$ edge, and break it up small, you have not only the original surface but a number of fresh surfaces, and as all these will be simultaneously lighted, the whole quantity will take a much shorter time to be consumed than when the cube was entire. Thus, other things being equal, a small grain powder is a quick burning powder.

You now grasp at once the effect of enlarging the grains; the action is rendered less violent, its intensity is dulled, as it were; the wave pressures which are practically useless in the production of velocity are got rid of, and the maximum statical pressure is lowered also by another circumstance which we must now take into account.

The old writers on gunnery were accustomed to consider that all the powder was converted into gas before the shot had sensibly moved, and with the violent powders in use in their day there was probably no great error in their assumption, which was a convenient one as it simplified calculation. If it were a true assumption the full pressure of the gas would be set up before the shot started, and we should always have pressures of about 38 tons on the square inch, that being the pressure observed by Captain A. Noble, of Elswick, in his experiments with powder exploded in closed vessels, the density of the charge being that of water, (27·7 cubic inches per pound).

Supposing a gun to be pointed vertically upwards, so that the full weight of the shot has to be raised by the gas, it is obvious that the longer the shot the greater weight there will be on each square inch of base. The shot of the 80-ton gun is the longest we have got, it weighs 1,700 lbs., and is 16 inches in diameter, this gives $8\frac{1}{2}$ lb. for each square inch of base; that is, directly a pressure of $8\frac{1}{2}$ lb. per square inch is exerted by the gas the shot must begin to move, even when the gun points to the zenith. As the maximum pressure, a steady uniform pressure be it remembered, amounts to about 20 tons, it is abundantly clear that the shot must have got under way at some period antecedent to the setting up of the maximum pressure; and not only must this be the case, but as the moving away of the shot leaves an increased space behind it in which the gas expands, the maximum pressure never reaches the normal 38 tons just mentioned; and the question resolves itself into a race between the powder and the shot, the powder trying to increase the pressure by giving off its gas, and the shot trying to reduce the pressure by leaving more room for the gas to expand in; at first the powder appears to be gaining till the maximum pressure is attained, but the shot "stays" the longest, and eventually wins. Where moderate charges of R.L.G. powder are employed in heavy guns, the shot has usually moved about one inch by the time the maximum pressure is set up; with pebble powder about 4 inches; with $1\frac{1}{2}$ inch cubes about 6 inches; and probably when the cartridges are air-spaced to 34 cubic inches per pound, the maximum pressure scarcely falls till the shot has moved about a foot.

As it is the maximum pressure which is most likely to strain or injure the gun and projectile, it is desired to keep this maximum pressure as low as possible, and to sustain it as long a time as possible, so as to impart the greatest velocity to the projectile; thus the ideal of the artillerist would be a charge so arranged that a pressure equal to the amount the gun is constructed to bear should be uniformly maintained till the shot has left the muzzle. We are a long way from this, but still a good deal has been done towards it in the last 7 or 8 years.

The effect of chambering out the end of the bore where the powder lies is practically to permit a small gun to burn effectively the charge of a larger one. The cartridge is shortened and the mechanical conditions of burning are greatly improved. Thus in experiments with a 9-pounder gun, service bore and service powder, it was found that by gradually increasing the charge a gain in velocity was obtained up to $2\frac{1}{2}$ lb. (service charge = $1\frac{3}{4}$ lb.), but that farther increase up to $2\frac{3}{4}$ lb. and 3 lb. gave no additional velocity. When the chamber was enlarged from 3″·0 (service bore) to 3″·6, the velocity continued to rise with the charge, till with 3 lb. cartridges the chambered gun gave an increase of more than 100 feet per second over the unchambered one, while the pressures were about 30 per cent. lower with the chambered gun than with the other. Also with $3\frac{1}{2}$ lb. in a 3″·8 chamber a velocity of about another 100 feet was obtained, the pressures still remaining moderate.

The amount of air-spacing most suitable for our heavy guns appears to be regulated by the weight of the column of shot on a square inch of base, since the inertia and rate at which the shot acquires velocity depend on this. Thus with $1\frac{1}{2}$″ powder for a 10″ projectile of 400 lb. the best density of the charge has been found by experiment to be about 28 cubic inches per pound; with the 12″·5 of 800 lb. about 30 cubic inches; and with the 16″ of 1,700 lb. about 34 cubic inches. The effect of decreasing the density of the charge is of course to diminish the maximum pressure. Thus while Captain A. Noble found that 38 tons on the square inch was the pressure in a closed vessel, when the ignited powder was at a density of 1·0 (*i.e* = water), he found that at a density of 0·8 (34 cubic inches per pound) the pressure was but 25 tons on the square inch. We are thus enabled to increase the charge of powder, and to provide an additional store of gas which comes into play as the shot passes up the bore, and so sustains the lowered maximum pressure for a longer time.

Thus we make some approach to the artillerist's ideal above mentioned, a moderate uniform pressure throughout the bore.

I have dwelt rather long on this part of my subject, partly because I feel great difficulty in making it clear, and partly because it is the key to modern progress in gunnery as regards the actual power of the gun with respect to penetration.

For medium guns, shell power, as has been said, is the prime object. I do not think a better illustration of the mode in which a gun is now designed to possess the maximum shell power can be given, than the genesis of the new experimental howitzers, of which you will find particulars in Table C.

The experiments at Eastbourne, as well as oft-repeated trials at Shoeburyness, showed pretty decisively that the howitzers now allotted to the siege train (*vide* Table A) are not all that can be desired with respect to accuracy, and that breaching with curved fire by their aid is a process demanding a larger expenditure of ammunition than can be always conveniently supplied. It was determined, therefore, to take a step in advance, and to produce something which, it was hoped, would more nearly correspond with modern requirements.

A gun is, of course, nothing but a machine, and, like other machines, must be constructed to fulfil certain definite conditions. In the present case these conditions admit of precise solution. For a piece capable of transport over a favourable country on a platform waggon, it was decided that the greatest admissible weight was 70 cwt. The next point is the recoil. The maximum velocities of recoil of the most lively pieces in the service is as follows:—

7-pounder	... ...	32 feet per second.
6″·3 howitzer	... ...	27 „ „
8″·0 „	... ...	28 „ „
64-pounder	... ...	17 „ „

The 7-pounder tumbles head-over-heels frequently, but being small, this is of little consequence; the two howitzers, when fired with their heaviest charges, are very difficult to manage, while the 64-pounder is quite manageable even on a travelling siege carriage. It was, therefore, decided that a maximum velocity of recoil of 20 feet per second might be allowed for the new howitzer. I must explain here that this velocity refers to the motion of the gun only, supposing it to be unchecked. In reality, gun and carriage move back together, and the initial velocity of recoil of the system is much less than the amounts above given. It would not answer, however, to reckon the momentum from this in constructing a gun, as a new variable—the weight of the carriage—would be introduced. We have now obtained a momentum of 70 cwt., moving at 20 feet per second velocity. Practically, the momentum of the projectile on quitting the muzzle is equal to the momentum of the gun at the same moment. Hence we have 156,800 as the number representing the momentum of our shell. Suppose we took a shell of 100 lbs. weight, we could afford to give it a velocity of 1,568 feet per second. But if we took a shell of 200 lbs. weight, we should find the recoil inconvenient if the muzzle velocity exceeded 784 feet per second.

We now come to a most important condition—what do we want the howitzer to do? The reply is—1st. to breach; 2nd, to bombard. It was then determined that the greatest breaching power required should be obtained at 1,500 yards, at an elevation of 5°. For longer distances, a greater angle would be used, and, of course, all shorter ranges would be covered by this trajectory. We have now a neat problem in ballistics, viz., to find the calibre of a shell about 3 diameters in length, of such a weight that, with the muzzle velocity required to give a range of 1,500 yards at 5° elevation, the muzzle momentum shall be 156,800. By the aid of Professor Bashforth's tables, this problem may be solved with ease, and after a few approximations, it is found that a shell 8″·1 in diameter, weighing 170 lbs., and having a muzzle velocity of 920 feet per second, will fit the conditions. For the sake of round numbers, the calibre is placed at 8″·0, and the first experiments will shortly be carried out to verify the calculations.

For bombarding it was laid down that a range of 5000 yards should be obtainable at 35° elevation; proceeding as before it was found that an 8-inch shell of 230 lb., with a muzzle velocity of 675 feet per second, would be sufficiently near the mark. Lastly, it was found that an 8-inch shell of 170 lb., with a pointed head somewhat approaching the Palliser form, and containing a good bursting charge, would be about $2\frac{3}{4}$ calibres long; and that a common 8-inch shell of 230 lbs., containing a very large bursting charge, would be about $3\frac{1}{2}$ calibres long—results which suit the purposes of breaching and bombarding excellently.

So much for the calibre. We now come to the proportions of the piece. It was at once decided to make the bore as long as possible, consistently with preserving a sufficient amount of metal over the breech to withstand the pressure of the gas. The reasons for this are that less pressure is required to produce a given muzzle velocity, that less strain is thrown on the rotating agent, and that the trunnions are thrown farther forward so that the leverage of the jumping action is thus lessened; the muzzle portion of the gun was made very strong and thick, partly with the object of advancing the trunnions, and partly because in a siege gun the muzzle is much exposed to the enemy's fire, and should therefore be strengthened, even at the expense of delicacy of appearance.

The 36 cwt. howitzer is constructed on precisely the same principles from data laid down as suitable to a light siege train.

The effect of shrapnel at fighting ranges in the field depends on the construction of the projectile and on the velocity possessed by it at the moment it opens and sets free its bullets. A field battery must carry a large number of rounds on service, and yet must possess great mobility; consequently, the weight of each projectile is rigidly limited. For a given weight of shrapnel, the broad, short form will hold more bullets and possess a better construction than is the case with long, narrow projectiles. It is somewhat easier also to obtain a high muzzle velocity with the larger calibre, at the expense, of course, of increased recoil. But, owing to the resistance of the air, the shrapnel of greater diameter will part with its velocity sooner than the more slender one will, and a maximum of efficiency at a fighting range will be found by a compromise between these two conditions; that is, for a given weight of projectile the calibre must be the smallest that will admit of a thoroughly effective shrapnel. It would never do, for instance, to give up an outer layer of bullets to increase the remaining velocity at burst.

We have only one more question of great importance to consider, and I will not tax your patience long with it.

However powerful our gun may be, as far as its capacity for effectively burning powder is concerned, the damage it does to the enemy will be dependent on the accuracy and efficiency of the projectile. You all know that with muzzle-loading systems the shot have been usually rotated by means of bronze studs let into their walls, while lead coating has been adopted for breech-loading systems. The studs weaken the projectiles; the lead coating is so much weight wasted. In fact, for penetrating purposes, the lead-coated projectiles were found to be about fifteen per cent. less effective than studded ones, other things being equal. The lead-coated shot were however slightly superior in accuracy. Such was the state of affairs up to about two years ago.

Shortly before that time the great wear of the surface of the bore due to the rush of gas over the projectile in muzzle-loading guns, had led to the adoption of a copper gas check, which is a flanged disc fastened on to the base of the projectile. It has now been found practicable to give rotation by this gas check, and to abolish the studs altogether. The grooves have been reduced in section and multiplied in number, and the tube of the gun is consequently less weakened, while the shot is free from stud holes or lead coating. The escape of gas is altogether stopped by the expansion of the copper disc, which indeed acts more satisfactorily than does the lead coating of the breech-loading systems, where the lands bite into the soft covering.

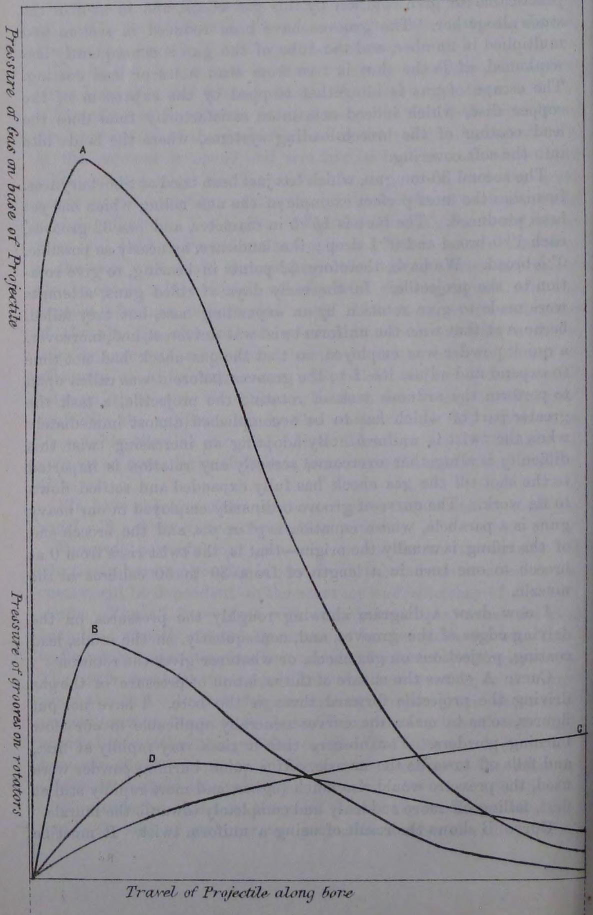
The second 80-ton gun, which has just been tried at Shoeburyness, furnishes the most perfect example of the new rifling which has yet been produced. The bore is 15″·5 in diameter, and has 32 grooves, each 1″·0 broad and 0″·1 deep; the lands are, as nearly as possible, 0″·5 broad. We have, therefore, 32 points in bearing, to give rotation to the projectile. In the early days of rifled guns, attempts were made to give rotation by an expanding base, but they failed, because at that time the uniform twist was universal, and, moreover, a quick powder was employed, so that the gas check had not time to expand and adjust itself to the grooves before it was called upon to perform the arduous task of rotating the projectile, a task the greater part of which has to be accomplished almost immediately when the twist is uniform. By adopting an increasing twist this difficulty is altogether overcome, scarcely any rotation is imparted to the shot till the gas check has fully expanded and settled down to its work. The curve of groove ordinarily employed in our heavy guns is a parabola, whose equation is $y^2 = p\,x$, and the breech end of the rifling is usually the origin—that is, the twist rises from 0 at breech to one turn in a length of from 30 to 50 calibres at the muzzle.

I now draw a diagram showing roughly the pressures on the driving edges of the grooves, and, consequently, on the studs, lead coating, projections on gas check, or whatever gives the rotation.

Curve A shows the nature of the variation of pressure of the gas driving the projectile forward through the bore. I have not put figures, so as to make the curves generally applicable to our slow burning powders. You observe that it rises very rapidly at first, and falls off towards the muzzle. If a quick burning powder were used, the pressure would rise much higher, and more rapidly still at first, falling off more suddenly and completely towards the muzzle.

Curve B shows the result of using a uniform twist. It must be

DIAGRAM OF PRESSURE INSIDE THE BORE



remembered that curve A represents the pressure on the base of the shot, while curves B, C, and D represent the pressure on the grooves required to do the work of turning the shot. Curve B, bears an invariable relation to curve A; in other words, when the twist is uniform the pressure required to give rotation is a constant function of the pressure driving the shot forward. For simplicity, I have put the function as one-third in the diagram.

Curve C represents the pressures on the grooves when the rifling is of the parabolic form, rising from 0 at the breech. No work is done at first by the grooves, and the maximum strain is much lower than when the uniform twist was employed. This answered very well when the rotation was communicated by studs, but the adoption of an expanding rotator brought some fresh considerations into play. The projections on the gas check are driven into the grooves, and kept up to their work by the pressure of the gas; now, in curve C you observe that the greatest part of the rotation is given as the shot approaches the muzzle; that is, where the projections on the gas check receive least support from the gas. This is obviously wrong, and though with light shot, as in field guns, it may make little matter, yet when we come to heavy shot, about four feet long, turned simply by the base, it is necessary to husband our resources.

It is inadmissible to take the uniform twist which would, of course, make the pressure of rotation exactly fit the driving pressure; because, as I said before, the gas check would not have time to expand before being heavily called upon to do its work We have therefore adopted a curve of groove, called the semi-cubical parabola $\left(y = p\,x^{\frac{3}{2}}\right)$ which rises from O at breech to one turn in fifty cals. at muzzle; curve D exhibits the nature of the pressures on the grooves with this new form of increasing twist, the results of which, so far, have been excellent.

I append a table (C) showing the guns now in the experimental stage, and giving the results which are expected from them should all turn out well. Time will not permit a lengthened description of each, but you will see by the details given that the principles I have been endeavouring to explain are being adopted in all. Chambering is required for the guns where high velocity is a desideratum, but not for the howitzers where low velocities and heavy shell are wanted. The polygroove rifling is coming in for all, except for the 12″·5 guns, of which great numbers are already in the service. Air-spacing will be used for the heavier guns.

TABLE C. *Guns in the Experimental Stage, showing anticipated Results.* *July, 1877.*

Nature, Calibre, and Weight of Gun.	Principal Object to be Attained.	Weight of heaviest Projectile.	Max. Service Muzzle Velocity.	Diam. of Powder chamber.	Weight and Density of Charge.	Rifling.	Perforation at 1000 yds.	Bursting Charge of Com. Shell about ;—	Remarks.
Muzzle-loading.		lb.	f.s.	ins.			ins.	lb.	
16"·0 of 80 tons.	Perforation of armour.	1700	1620	18·0	425 lb., 1½" cubes at 34 cub. ins. per lb.	Polygroove. Rotation by gas check. 33 grooves, each 1" broad. Twist 0 to 1 in 50 cals. Semi-cubical parabola.	28·5	125	Experiments nearly concluded, but chambering not yet decided on.
12" 5 of 38 tons.	Do.	810	1580	14·0	200 lb., 1½" cubes at 30 cub. ins. per lb.	Woolwich grooves. Rotation by gas check. 9 grooves, each 1"·5 broad. Twist 0 to 1 in 35 cals. Parabola.	20·7	55	Do. do. Many guns are already issued, and it is doubtful whether studded projectiles (fitted with gas checks) will be continued.
64 pr. of 64 cwt., present calibre 6"·3.	Perforation of masonry & earthwks.	100	1550	6"·8, bore to be 6"·6.	25 lbs., pebble, at 26 or 27 cub. ins. per lb.	Polygroove. Rotation by gas check.			Experiments for increasing the power of these guns recently determined upon.
12 pr. of 8 cwt., calibre 3"·0.	Shrapnel power against troops.	12	1700	3"·6	3 lb., field gun powder, at 27 cub. ins. per lb.	Polygroove. Rotation by gas check. 10 grooves, each 0"·5 broad. Twist 0 to 1 in 30 cals. Parabola.		14 oz.	Experiments nearly concluded. Pattern of shrapnel still undecided.
70 cwt. howr., probable calibre, 8"·0.	Shell power for bombarding. Breaching power.	230 170	675 940	Same as bore.	Not fixed.	Polygroove. Rotation by gas check.			Experiments recently determined upon.
36 cwt. howr., probable calibre, 6"·6.	Shell power for bombarding. Breaching power.	135 95	610 845	Do.	Do.	Polygroove. Rotation by gas check.			

Perhaps it will be said that it would have been more logical for me to have given you an account of the powers of the guns of foreign nations, as it is against them that you will have to construct defences. This is no doubt a true criticism, and I can only plead that the time is too short to permit me to enter upon such a large subject; perhaps also you will pardon the boast if I own to a conviction that if you make your works strong enough to resist our own guns, you need not fear those of other countries.

E. MAITLAND,

July, 1877. MAJOR, R.A.

PAPER XII.

PRÉCIS OF PAPERS

CONCERNING THE INTRODUCTION OF

CAVALRY PIONEERS.

Communicated by the Secretary Royal Engineer Committee.

November, 1876.

Cavalry Pioneers.

Report on the introduction of Pioneers in the British Cavalry.—

The Committee appointed by Adjutant General's letter of 24th November, 1875, to consider the above subject, have made the following report.

Some organization should be adopted, to enable the cavalry to perform efficiently all their important functions in the field.

The duties they may have to perform may be classed under two heads—

(*a.*) *Those necessary in camp*, as shelter in bivouac, field filters, improving water supply, arrangements for watering horses, cutting brushwood for hurdles, fascines &c., making approaches to watering places, &c.

(*b.*) *Those requiring little technical knowledge and but few simple tools*, as shelter trenches, shelter and gun pits, barricades, finding fords, crossing ice, improving roads, making ramps, bridging ditches, cutting telegraphs, delaying use of a railway, destroying bridges, ramps, roads, &c., stopping fords, and tampering with telegraph lines.

There appears to be three modes by which the object sought might be obtained, these are—

(*a.*) By training certain Officers, N.-C. Officers, and troopers, in each cavalry regiment, to perform the duties.

(*b.*) By having mounted sappers to accompany the cavalry, *(c.)* By a light engineer train of a few carriages, with some mounted men.

The *first* of these plans is adopted in Austria and Germany, and is being tried in France and Russia. The *second* was partially carried out in the American Civil War. The *third* has not yet been tried to any extent.

Advantages and disadvantages of the above plans—

(*a.*) Regiments with *cavalry pioneers*, though dependent on their own resources, could not execute extensive demolitions. The men would still be effective sabres of their regiments, but there is a danger of their training being neglected.

There is also a danger of the pioneers being withdrawn from their regular duties, when there may be a deficiency of sappers.

(*b.*) *Mounted sappers* could execute demolitions and restorations in a more complete manner, probably, than pioneers.

The sappers not being part of the regiment, would be able to be kept up to their mark by constant practice. Not having to act as cavalry, they could carry more tools than cavalry pioneers.

(*c*) *The light Engineer Train* could execute more extensive demolitions, and make more substantial restorations than pioneers, or mounted sappers. Like the Royal Horse Artillery, they could accompany the cavalry brigade, and the mounted portion could follow the cavalry anywhere. More tools could also be carried by them, and fewer horses would be required for carrying them.

After considering these plans, the Committee decided unanimously that it would be for the good of the service if cavalry pioneers were introduced.

On considering the duties which cavalry pioneers should be instructed to perform, the Committee decided that there should be certain men in each troop, capable of performing the camp duties before mentioned, who should be called *camp pioneers*. All Officers and N.-C. Officers should be acquainted with these duties.

It was also thought advisable to train certain men to perform the regimental duties mentioned in clause *b* above; these men to be called *regimental pioneers*.

Any duties requiring superior skill than the above, are essentially engineers' duties, and have no reference to the cavalry.

The Committee recommended *one N.-C. Officer and four privates* to be chosen in each squadron for *camp* duties, and also *one N.-C. Officer and four privates* in each squadron for *regimental* pioneer duties, (when on *active service*.)

When these pioneers assemble for regimental work they should be under the charge of a specially selected subaltern.

For the peace establishment the Committee recommend that there should be *one N.-C. Officer and two privates* per troop, rated as *regimental pioneers*, and two privates as camp pioneers. These pioneers to be selected from men acquainted with their duties as soldiers, and at least 19 years of age. Privates to cease to be pioneers after 15 years service, or after the age of 33 years.

These pioneers to be taught when with their regiments, but it is recommended that the subaltern, and one N.-C. Officer per troop, be sent for instructions at the S.M.E., Chatham, to obtain certificates from the Commandant as to their efficiency and ability to instruct others.

As soon as a regiment obtains a properly qualified officer, the instruction is to commence, and the officer will give certificates to those privates who qualify as regimental pioneers.

To ensure efficiency and uniformity in the instruction, the Committee recommend an annual inspection by a R.E. Officer.

The pioneers to be similarly armed and accoutred to their comrades, and to have besides, the charge of certain tools.

In order to carry the latter more conveniently, and to lessen the weight, the near horse shoe case to be omitted from the pioneers' saddles.

The Committee proposed the following equipment for the pioneers of each troop.

N.-C.O. carries—

1 leather pouch, with vesuvian match case; 1 holster wallet containing 2″ bull nose screw auger, 16″ long; also wooden detonator holder, containing six detonator's, with 2′ Bickford's fuze attached to each.

1 holster wallet containing auger handle, waterproof bag, and 32 gun cotton discs $1\frac{3}{4}''$ diameter and $\frac{1}{2}''$ thick, 20 yards of No. 22 B.W.G. soft iron wire.

Total additional weight for the N.-C.O., 5lbs. $4\frac{1}{2}$ozs.

No. 1 carries—

15′ of 1″ white lashing rope, and a light helved pick in leather case.

Total additional weight for No. 1, 1lb. 8ozs.

No. 2 carries—

15′ of 1″ white rope, and a cast steel light shovel in leather case.

15′ of 1″ rope, 20 4″ cut nails, and 2lb. hand axe in leather case

Total additional weight for No. 2, 1lb. 6ozs.

No. 3 carries—

Total additional weight for No. 3, 1lb. 0½oz.

No. 4 carries—

2 15′ lashings of 1″ rope, an 18″ hand saw in leather case, a 5″ three square hand saw file with handle, a hand saw set, a 2′ four-fold rule, and pincers or nippers.

Total additional weight for No, 4, 1lb. 9½ozs.

The *farrier* carries, instead of the felling axe, &c. weighing 7lbs. 13oz., the following articles—

1 holster wallet containing 20 4″ cut nails, a wooden detonator holder, and 6 No. 8 detonators, with 2′ Bickford's fuze attached.

1 holster wallet containing, 1 waterproof bag, 32 gun cotton discs, and 100 yards No. 22 soft iron wire.

Total diminution for the farrier 0lbs. 14¾ozs.

After considering the explosive to be employed, the Committee rejected *dynamite* as being dangerous, and *wet granular nitrated gun cotton* as being no stronger than ordinary compressed gun cotton.

Compressed gun cotton was selected, in the form of discs, 1¾″ diameter and ½″ thick, weighing 1oz., as capable of producing the best effect.

Each *charge to* consist of 8 *discs*, 4 such charges being carried in a waterproof bag, in a leather case.

A charge of 8oz. will destroy a rail or timber piece.

The discs to be of *dry* gun cotton.

Each detonator to have 2′ of Bickford's fuze attached to it, the end of which should be fitted with quick match, and be covered with a waterproof cap.

For lighting the fuze, vesuvians are to be used.

The *tools selected* to be carried by the pioneers, are the light infantry pick and shovel, weighing respectively 2¾ and 2½lbs.

The 2lb. hand axe to be carried, instead of the 6lb. felling axe now carried by farriers.

Each squadron to carry 6 picks, 12 shovels, 2 spades, 2 felling and 6 hand axes, available for camp and also for regimental pioneer work. An 18″ hand saw, weight 12ozs. to be carried, instead of the ordinary hand saw, weighing 1¾lbs.

The auger to be a 2″ bull nosed screw auger, 16″ long, weighing 2¼lbs. When necessary, the regimental supply of gun cotton, &c., is to be replenished from the R.E. Field Park.

As pioneers would be excused no regimental duties, and would have more work to do than their comrades, some additional pay is recommended.*

A small quantity of gun cotton, &c., to be allowed for instruction, &c.; also that dummy charges be carried in time of peace, though the necessary supplies are to be available when required.

End of Committee's Report, dated 17-2-76.

Simultaneously with the action taken by the above Committee, the Commander-in-Chief in India brought to the notice of the Indian Government, the desirability of a regular pioneer equipment in the Indian army, urging its necessity, and citing the Austrian and other armies as instances.

The objection to pioneer equipment is the extra weight to be carried, but this is counterbalanced by increased efficiency.

The following pioneer equipment was therefore recommended, viz., 3 *spades*, 3 *picks*, *and* 3 *axes*, for each cavalry troop, no single portion of these tools was to weigh more than 3lbs., and no single tool more than 6lbs.

These tools were accordingly made at Roorkee, and issued to five regiments to be tried at the Delhi camp.

After a short trial the following reports were sent in:—

From Officer Commanding 10*th Hussars.*

10*th Hussars*	Carries them all easily (except the long handled shovel) attached to saddles; approves of all patterns except the short spade. Has not however had an opportunity of trying them practically. Makes several other suggestions.

From Officer Commanding 11*th Hussars.*

11*th Hussars*	Reports that they do not answer the purpose for which supplied, and are very awkward to carry. Has lost the small hatchet supplied.

From Officer Commanding 15*th Hussars.*

15*th Hussars*	The six tools carried easily by three farriers. Condemns the spade, shovel, and picks. Approves of the hatchets.

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* This was not approved by H.R.H. the Commander-in-Chief.

From Officer Commanding 10th Bengal Lancers.

10th Bengal Lancers. — Reports the tools easily carried on the saddles, except the shovel. Does not consider the tools adapted for natives to work with, and suggests the hoe, phowrah, and bill-hook. Makes other suggestions.

Officer Commanding 1st Regiment, Central India Horse.

1st Regt., Central India Horse. — Reports that he has carried the tools in cases, on the off side of the saddle. They are easily carried, except the shovel, which is difficult. Approves of the long pick, hatchets, and shovel.

Condems the small spades and pick, with screwed handles, as useless.

Suggests the phowrah, instead of the spade, for native troops.

Reports that the edge of the axe breaks when cutting green wood, and that being of English steel, it cannot be repaired. Suggests native metal for hatchets, as being easily sharpened and repaired.

Owing to the varying nature of these reports, the tools were tried practically before the Commander-in-Chief in India, by parties of the 11th and 15th Hussars, and 10th Bengal Lancers, the result of the trial being, the condemnation of the shovel, long pick, and long handled axe, and the approval of the small spade, short pick, and hatchet.

Shortly after this (in Sept., 1876) it was decided by the Government of India, that a further trial should be made, before introducing the equipment throughout the Cavalry in India.

The Commander-in-Chief accordingly selected the following three regiments, the 15th Hussars, 10th Bengal Lancers, and 14th Bengal Cavalry, in which a further trial of the proposed cavalry equipment might be carried out.

As it was thought impracticable to carry out the course suggested in the Committee's report, it was considered sufficient to teach the men practically, as far as could be done, the subjects in clauses *a* and *b* on page 1. (Camp and Regimental duties.)

The issue of three picks, three shovels, and three axes, to each troop of the three regiments above named, was accordingly demanded and sanctioned.

The introduction of pioneers into the British cavalry, having been approved of by the Commander-in-Chief, four regiments were selected for the purpose of trying the new system.

One subaltern and one N.-C. Officer of each regiment were ordered to be detailed for instruction at the S.M.E., Chatham, where they should receive about eight days instruction in the duties mentioned in clause *a*, and about twelve days instruction in those mentioned in clause *b*; the total duration of the course to be about one month.

Cavalry Pioneers in the Austrian Army.—

Before 1866 many of the Austrian Cavalry regiments had pioneers, who rendered such good services during the war, that it was decided to organize them in all the cavalry regiments.

These pioneers, selected from the men of the regiment, were clothed, armed, and equipped, like their comrades, except that they carry one tool in a leather case. They also receive a simple training as pioneers, after they have first passed their first-class in riding drill.

General Edelsheim's aim in creating this organization was to render the cavalry independent of the other arms, when acting as an advanced guard, by enabling it to surmount obstacles, &c., and the experience of eight years, has justified his experiment.

The officers in charge of the pioneers receive a few months instruction with engineers, and the pioneers soon acquire their special technical instruction. During the war of 1866, we find the pioneers distinguished themselves in the following ways :—

In defending bridges, villages, &c.
Forming roads of approach.
Blocking roads.
Destroying bridges.
Forming works to facilitate the employment of Artillery, and opening up roads for the same.
Breaking down palisades.
Clearing woods, &c.

The cavalry pioneers have a double duty, viz. :—

1st. To render possible the passage of obstacles in as short a time as possible.

2nd. To assist in the rapid formation of camps and bivouacs.

These duties necessitate the use of the two following classes of pioneers, in each cavalry regiment, viz. :—

1st. The *section* called the *regimental pioneers* (highly trained) and

2nd. The *squadron pioneers*, of which there are five to each squadron (except the 6th, which has none), for camp or fatigue duties.

The pioneer section furnishes the advanced guard, and the squadron pioneers perform the necessary duties at halt or bivouac. The pioneers for the pioneer section are selected from men having one, two, or three years service. The work taught is as follows :—

1st. First principles, use of tools, &c.
2nd. Construction of roads, &c.
3rd. Crossing watercourses, with and
4th. Without bridges, &c.
5th. Destruction of railways, &c.
6th. Camp duties.
7th. Hasty fortifications.

A cavalry pioneer section consists of 40 men, and one officer.

The tools carried by the pioneers are only four in number, viz :—

Spade and case	weighing	4·96	lbs.
Pickaxe	,,	6·28	,,
Hatchet	,,	3·42	,,
Axe	,,	6.83	,,

and of these, each regiment carries 22 spades, and 11 of each of the other tools.

Each regiment also carries 11 valises, containing pincers, file, jointed saw, claw hammer, pack thread, 75 nails and 2 spikes.

In war time each pioneer section carries 40 cartridges, each one containing 2 lbs. (Austrian) of dynamite.

The cartridges consist of a steel cylinder with oval base, filled with 2 lbs., (Austrian)* dynamite in the oily state.

The primer used is a cylindrical box fixed in one end of the steel cartridge, and containing a small quantity of dynamite; it is fired by a cap into which the end of a Bickford's fuze is inserted.

The objection to the extra weight placed on the horses has not proved insurmountable in the Austrian Cavalry, which has smaller, and more lightly built, horses than the British Cavalry.

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* A pound or pfund Austrian equals 1·234 English lbs.

Destruction of Railways and Telegraphs by Prussian Cavalry.—

The Prussians have provided their troops with the necessary equipment and instruction, in destroying railways and telegraphs.

The pioneers are instructed in all the details of the permanent way, as well as with the construction and destruction of telegraphs. The tools carried by the cavalry pioneers are the key, auger, petard, grappling tackle, and cavalry hatchet.

Each squadron carries these tools, when on the march, in squadron carriages, and when on an expedition, on the horses. One N.-C. Officer and six troopers can dismantle a portion of a railway in ten minutes.

The following are some of the Prussian instructions on the subject, viz. :—

1st. No line to be cut without an officer's order.

2nd. Cavalry should always try to destroy lines in rear of the enemy.

3rd. All lines between the two armies to be respected in offensive movements.

4th. In retreat the Commander-in-Chief details the lines to be preserved, and those to be dismantled or completely destroyed.

5th. No work of art to be destroyed without special orders from the Commander-in-Chief.

M. T. SALE, Captain, R.E.,
Secretary R.E. Committee.

PAPER XIII.

EXTRACTS FROM PROCEEDINGS

OF

INDIAN PONTOON COMMITTEE.

Communicated by the Secretary, Royal Engineer Committee.

PROCEEDINGS of a Committee assembled at the Army Head Quarters, Camp Delhi, on the 18th January, 1876, in accordance with G.O. No. 100, of the 10th January, 1876, by the Right Honorable the Commander-in-Chief, to report on the description of Pontoon and Trestle Equipment best suited for India.

The Committee assembled pursuant to orders, and proceeded to consider the subject upon which they were ordered to report.

2. The Secretary informed the Committee that portions of the following equipments were in charge of the Corps of Bengal Sappers and Miners.

1.—Pasley's old pattern equipment.
2.—Pasley's new pattern equipment.
3.—Blanchard's infantry equipment.
4.—A light equipment designed for service in Abyssinia.
5.—The Austrian (Birago) equipment.
6.—An equipment lately made at Roorkee on the basis of that recently adopted at home, and consisting of both pontoons and trestles.
7.—A light equipment for mule transport. Of these Nos. 2, 6, and 7, were reported to be in camp at Delhi, and the remainder at Roorkee.

Note.—For brevity's sake these various equipments will be designated in this report by the numbers attached to them above.

3. The Committee were also informed that in England No. 1

was tried about 25 or 30 years ago in competition with Blanchard's heavy equipment, and that the latter was finally adopted for home service after an exhaustive series of experiments, and continued in the service until the year 1871, when it was replaced by an equipment determined upon report by the Standing R.E. Committee at Chatham, which had spent several years and much labour in the investigations and experiments connected with the subject. This last equipment is now the service one in England, and is understood to be considered very satisfactory.

4. In India No. 1 equipment was adopted 30 years ago, and being found deficient in floatation, and some other points, was modified, it is believed by Sir C. Pasley himself, into No. 2, which is now the service pontoon equipment in this part of the country.

5. The government having come to the conclusion that this equipment was not satisfactory, and that it might be improved upon, appointed a Committee in 1864, of which Lieut.-Colonel (now Major-General) A. Taylor, C.B., R.E., was President, to report upon the matter. No action was, however, taken on the report of this Committee.

6. In 1866 a quantity of Austrian equipment was made up and tried at Roorkee, but was not adopted into the service. More recently government sanctioned the construction of No. 6 equipment as an experiment, and this has been under trial more or less for two years. It is now in charge of one of the pontoon companies of the Sappers and Miners.

7. The lighter equipments have been constructed or received from England at various times, No. 7 having been only just completed, and not yet tried.

8. The Committee were of opinion that the reports of the proceedings of the R.E. Committee at Chatham, and of General Taylor's Committee of 1864, should be laid before them for their guidance; being satisfied that the best way of solving the questions entrusted to them within the time available for their consideration, is to adapt the home equipment as far as possible, to such special local conditions as may interfere with its adoption pure and simple, in this country. The Committee decided that their immediate object should be to test and compare the various equipments actually available under all possible conditions.

9. The Committee proceeded to the Sappers' and Miners' Park, where they inspected Nos. 2 and 6 equipments which they found there, noting several points for future trial and discussion.

10. The Committee assembled on the 20th January, 1876, at the Sappers' and Miners' Park (present the same members as before), and marched portions of No. 2 and No. 6 equipments across country to a point on the Jumna, which had been selected for bridging operations. In moving across country they observed a difference between the two equipments as regards mobility, which was in favour of No. 6.

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25. The Committee having made a number of experiments to ascertain the buoyancy of No. 6 equipment, were of opinion that these results were not sufficiently decisive to warrant the adoption of definite conclusions, but that the following points appeared to have been established :—

1.—That the flotation of the two descriptions of pontoons tried was insufficient.

2.—That the general arrangement of No. 6 equipment appeared to afford a basis for future experiment, but that further investigation, particularly into the question of transport, is required.

3.—The Committee were of opinion that bullock draught is entirely unsuitable to the requirements of a pontoon train in India in the present day.

4.—The Committee after perusing a copy of the proceedings of General Taylor's Committee (produced by Captain Blood from his office records), expressed no opinion as to the necessity, or otherwise, of pontoons being decked in; they wished first to consider the report of the proceedings of the R.E. Committee at Chatham, who recommended the partially decked pontoon now in the service at home, and to experiment further on the point.

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29. A bridge was formed over the Jheel Drain on the 26th January, 1876, with No. 2 equipment, the work taking 58 minutes. A detachment of Sappers, in fours, was marched on to the bridge, and there halted, and closed up. The Committee observed the heading up of the water at the stems of the pontoons, with a view to comparing it with the result of a similar experiment to be tried with No. 6 equipment.

30. Another bridge was then formed in exactly the same place with No. 6 equipment, the work taking 15 minutes. A crowd of men, as before, was placed on the bridge also, and the heading up

noted; no very obvious difference between the amount of heading up of water was, however, apparent in the two cases; the current, which was considered to be about $3\frac{1}{2}$ miles per hour not being sufficient to produce this effect in any very marked degree. The want of more flotation in No. 6 equipment was again apparent, the pontoons being immersed almost level with their decks.

31. The chief value of the experiment was that it showed what a difference existed in the rates at which bridges could be formed with the two equipments under circumstances as nearly as possible alike. The bridges were 60 feet long, and were formed at the rates given below :—

No. 2, 10·34 feet, in 10 minutes.
No. 6, 40 feet, in 10 minutes.

* * * * * *

33. It having been found (*ante* para. 25), that the flotation of No. 6 equipment was insufficient, it was decided to have a portion of that equipment arranged with pontoons at reduced intervals; and also to try whether, with such reduced intervals, a whole bay could be carried on a single carriage. Accordingly orders were given to reduce the intervals of 16 bays from 15 feet to 12 feet, to send the bridge thus arranged for trial to Hurdwar, and to prepare a carriage for a whole bay thereof.

34. The Committee then proceeded to try experiments in ferrying men in the pontoons of No. 6 equipment across the Ganges Canal at Roorkee. It was found that 15 unarmed natives besides a crew of four (two oars, one steersman, one bowman), could with ease and rapidity be ferried across the Canal, which was running about three miles per hour at the time.

35. It was decided to repeat this experiment the following morning with armed British soldiers, and to ascertain whether they could use their arms conveniently in the pontoons if required.

36. The Committee were fully impressed with the absolute necessity of providing some arrangement for ferrying troops across a river before or during the formation of a bridge, and they considered that the pontoons under trial met this requirement in a very satisfactory way; but they were of opinion that if these pontoons could be provided with some arrangement for closing them when required, their safety in bridge would be much increased thereby. Orders were accordingly given to have one pontoon fitted with light hatches for trial.

* * * * * *

45. On the 21st of February, 1876, a bridge was formed over a branch of the Ganges, at Hurdway, consisting of fourteen pontoons and one trestle, the anchorage being arranged by means of a wire rope passed across the river partly in and partly out of the water —about one-third of its length being under water.

46. A gun carriage made up to the weight of a 12-pounder Armstrong, without limber, was drawn over the bridge by hand. It was observed that the bridge would have carried a greater weight than this, probably to the extent of carrying a 16-pounder, M.L.R. under the same conditions.

57. Forty men were placed on two bays of the bridge, and it was considered that the intermediate pontoon was immersed as deeply as was considered safe; a wave raised by the force of the current (afterwards ascertained to be upwards of six miles per hour), washed occasionally over the decks of the pontoons. With the temporary hatch proposed by the Committee (*ante* para. 36), probably a greater load would have been admissible.

48. The same two bays were afterwards loaded with chesses until the centre pontoon was immersed to about the same extent as in the experiment with the men; the load on this pontoon was found to be 3285 lbs.

49. The Committee assembled, present the same members as on the last day, and proceeded to discuss the results of the experiments with a view to settling certain points as data for calculations.

50. The following points were agreed to:—

a As regards the maximum weight to be placed on the carriages of the equipment, the Committee found that the wagons of No. 6 equipment, weighing complete under 33 cwt., were not moved over deep sand and rough country without some difficulty with the existing transport, commissariat bullocks. They considered that these conditions were likely to occur on service, and should be provided for. Hence they arrived at the conclusion that the weight of pontoon carriages for Indian service should never exceed 35 cwt., as a maximum, and accordingly laid that down as a limit; making no exception on account of horses, since the object of providing horses instead of bullocks would be to secure greater speed, which would entail carrying the men in the pontoon wagons, and so increasing their loads probably to the extent of about 5 cwt. each.

For a two-wheeled cart carrying any part of the bridge equipment it was laid down that 20 cwt., should be the maximum weight.

b A width of roadway of 9 feet clear having been approved by high authority for home service, the Committee decided upon that dimension as a minimum.

c The chesses forming the roadway should be $1\frac{3}{4}$ inches thick as a minimum, for the best teak wood.

d The maximum length of a single piece of a pontoon was assumed at 21 ft. 7 ins. (the length adopted for home service), as a basis for calculation.

e The greatest number of men that can be made available to work this length has been found to be 16; and consequently the weight of a single pontoon piece should not exceed 1000 lbs., or about 63 lbs. per man. Clarkson's material should be tried in this country, although the Committee felt very doubtful of its success in the Indian climate.

f Pending the trial of Clarkson's material for the covering of the pontoons, the choice appeared to be between copper and sheet iron, both of which have been tried in this Presidency. The opinion of the Committee was decidedly in favor of copper.

50. After the discussion, which led to the results detailed above, the Committee proceeded to the bank of the Ganges, where a bridge was formed at the same place as before with thirteen pontoons and two bay trestles, one on each bank.

51. A column of fours of unarmed natives, which covered all the floating portion of the bridge, was marched across in quick and double time. No sway whatever was perceptible in the bridge.

52. A raft was afterwards formed with two pontoons and moved across the stream by means of ropes worked from the bridge. No difficulty whatever was experienced in moving this raft about with a 12-pounder gun (without limber) upon it, and it was considered that with a raft of three pontoons instead of two, and suitable arrangements as to ropes, no difficulty should be experienced in moving a 40-pounder Armstrong over the river in the same way.

53. It was thought unsafe to attempt to row a raft in the rapid current for fear of its being carried away against the canal bridge below.

54. A pontoon was dismounted from a wagon and launched, and a crew of two rowers, one steersman, and a bowman, together with fifteen unarmed Sepoys as passengers, were placed on board in one

minute. The pontoon was afterwards rowed across the stream, sixty-four yards wide, with a maximum current of 6·2 miles an hour, and the men disembarked, all in 2 minutes 11 seconds, or in 3 minutes 11 seconds from the commencement of the unloading of the pontoon.

55. During these operations the rate of the current just below the bridge was determined, and was found to be 6·2 miles per hour, in one portion of the stream.

56. The formation of the bridge (68 yards long) took 45 minutes on these occasions; not including the placing of the wire rope to which the cables were secured. This operation took four hours, and was rendered necessary, as anchors could not be used owing to the great velocity of the stream and unfavourable nature of the bottom.

57. The Committee were much impressed with the great handiness and utility of the pontoons when used separately as boats in conveying ropes across the stream, and in other work connected with placing the wire cable alluded to above. This operation would have been much more difficult with pontoons which could only be used in rafts; unless, of course, special boats were carried with them as part of the equipment.

* * * * * *

68. The Committee assembled on the 2nd March, 1876.

69. They found on inspecting tables which had been prepared for them, that it was impossible to carry a complete bay of No. 6 equipment on a single wagon, even at 12-feet intervals, within the limit of weight laid down; and they accordingly decided that the 12-feet interval should be rejected, as it was open to many objections, and that no interval less than 15 feet should be recommended.

70. The Committee then proceeded to lay down the conditions which they considered should govern the design of a pontoon equipment for Indian Service, in continuation of the proceedings of the 22nd February, 1876. The following points were agreed to after prolonged discussion :—

a. The duty of a bridge train in India is two-fold. In the first place it should supply the wants of an army advancing rapidly in any country in which it might operate; taking ordinary conditions as to size of rivers, rapidity of currents, and weight of passing loads; and secondly it should be capable of furnishing a bridge of very high power for rivers of great width and rapidity, and for very heavy loads. These classes of duties may be entitled those of the " Advance " and " Heavy " bridges respectively.

b. The conditions of safety for these bridges should be as follows :—

Advance Bridge.

With infantry, in fours, crowded at a check (560 lbs. per foot run of roadway) there should be a margin of one foot from the water to the lowest point at which it could enter the pontoon. With the 16-pounder M.L.R the same.

With a crowd at the rate of 84 lbs. to the superficial foot of roadway, there should be a margin of 6 inches from the water to the nearest point at which it could enter the pontoon.

Heavy Bridge.

With a load at the rate of 100 lbs. per superficial foot of roadway there should be a margin of one foot from the water to the lowest point at which it could enter the pontoon. The same with siege artillery. With the maximum possible load of (say) 133 lbs. per superficial foot of roadway, a margin as above of 6 inches.

71. The Committee considered that it would often be advantageous to provide a double roadway with the heavy form of bridge, when only light traffic was expected; and that arrangement should be made with this object.

73. Calculations were inspected which showed that a pontoon within the dimensions of the English one, but modified in form, would fulfil all the conditions laid down.

74. It was resolved that these calculations should be carefully checked, and that tables should be prepared showing the distribution of the stores, as per approved list, on carriages weighing not more than 35 cwt. each, when loaded complete; which, supposing the calculations correct, would give three carriages to two complete bays of pontoon or trestle equipment, at 15 ft. intervals.

75. It was decided that ribands, with halved ends, like those of the home equipment, should be tried ; and that the length of chess for a 9-feet roadway should be left an open question pending the trial of these ribands.

76. The Committee did not approve of the English pattern of baulk with halved ends; since such baulks were not in their opinion

so useful as the ordinary pattern with full ends for making bridges with country boats and casual materials; a very important point for Indian service.

*   *   *   *   *   *

82. The Committee having resumed their consideration of the bridge train on the 3rd March, 1876, calculations were submitted by the Secretary, showing that a pontoon of the following dimensions would fulfil all the conditions of the "Advance Bridge":—

Length at top		21 feet	7 inches.	
Width Amidships	On deck	5 ,,	3	,,
	At bottom	4 ,,	6	,,
Width on deck at bow		4 ,,	6	,,
Width at square stern	On deck	5 ,,	3	,,
	At bottom	4 ,,	6	,,
Depth	From deck	2 ,,	$4\frac{1}{2}$	,,
	From top of coaming	2 ,,	$3\frac{1}{2}$	,,
Depth at bow		2 ,,	$8\frac{1}{2}$	,,

The bow to be shaped as in the present Roorkee equipment (No. 6), and the general construction to be the same as in that equipment, but the stern to be square, with a view to enabling a heavy bridge to be formed by doubling the pontoon pieces of the advance bridge.

83. As the calculations were found to be correct, and as they showed that the pontoon proposed met all the requirements laid down by the Committee, the above arrangement was approved.

84. With reference to Trestle Equipment, the Committee approved generally of that which they found in use at Roorkee, and which they were informed had been extensively tried during upwards of 4 years. They had, however, no opportunity of comparing this trestle practically with any other.

85. Tables showing the scale and distribution of bridge stores were approved, as was also a scale of miscellaneous tools and stores for a unit of bridge train.

86. With reference to transport, the majority of the members of the existing Committee did not think it necessary to the efficiency of the bridge train that the whole of it should be horsed, as recommended in the proceedings of the 22nd January, 1876, and they accordingly felt at liberty to propose a scale of transport consisting partly of bullocks, which was ordered to be included in their report. At the same time the Committee wished to record a very strong opinion that it is absolutely necessary to provide bullocks of the

best quality for the bridge train, and to attach them permanently to the Corps of Sappers, as is done with heavy batteries; the drivers and others being placed on the same footing as to pay as in the Artillery.

87. A scale of transport was also approved for the various telegraph equipments and was ordered to be included in the report of the Committee.

88. The Committee then adjourned, and the members then separated to their various stations.*

* * * * * *

6th March, 1877.

89 The Committee having been reconstituted assembled pursuant to order, read over and considered the proceedings of last year, and the papers connected with the subjects on which they were ordered to report.

90. The secretary explained that after General Stewart's Committee separated, arrangements were made for the construction of 4 pontoons with superstructure, and 2 waggons on the pattern approved by them, and that these stores were complete and ready for trial. He also stated that as it was felt to be desirable that these pontoons should be actually tried before being recommended to Government, no formal report had yet been submitted.

91. The Committee then proceeded to a tank, where 3 pontoons of the pattern proposed by last year's Committee were formed into bridge singly in the "advance" form, and a load of sand-bags was placed on the bridge to test the flotation and the strength of the pontoons. When a load of 7,400 lbs. each had been placed on a pair of pontoons, a diagonal strut in one of them gave way, and the pontoon was removed for repair.

92. Orders were given that all the corresponding struts should be strengthened in the 4 pontoons with a view to further trial, and to determine their proper dimensions. These dimensions, as well as those of all other parts of the pontoons, had been reduced as far as seemed possible, with a view to lightness.

93. A gun carriage made up the weight of the 16-pounder M.L.R. was then run across the bridge several times and the effect was noted.

94. It was observed that the amount of flotation provided was ample for this load, as when the pontoons were floating upright

* The Committee was dissolved after March, 1876, and reconstituted in March, 1877; only tw o members of the former Committee being on the second or reconstituted Committtee.

they were only immersed to within 14 inches of the tops of their coamings, giving 2 inches more height than is required by the conditions laid down by General Stewart's Committee (Proceedings, para. 70).

95. It was found, however, that the pontoons when loaded with both the above weights were laterally unstable, and tipped over until the edges of their coamings came in contact with the lower part of the roadway. This point was carefully examined, the gun carriage being repeatedly run over the bridge and halted on it, and the Committee agreed that it formed a fatal objection to the use of the pontoons as they stood, especially in rapid currents. Arrangements were made for placing stops at the sides of the pontoons, to come in contact with the roadway and check the tipping tendency, and to try this on the following day.

96. The Committee then inspected the 2 waggons which had been prepared, and observed that owing to a change which had been made in the way of carrying the pontoon, 4 inches could be added to its width at top and bottom, which would give additional flotation, and thus enable the pontoon to be reduced in height, which would increase its steadiness in the water. They also agreed that 5 inches might be added to the length, making it 22 ft. instead of 21 ft. 7 in., and that the extra length should be utilized in giving a more sloping bow.

97. The Committee again saw the carriage loaded up to the weight of the 16-pounder M. L. R. run over the bridge as altered according to yesterday's orders, and crowded men were also marched over it; but they were not satisfied with the working of the stops, which they considered inefficient and likely to interfere with the formation of the bridge in some localities; especially where there happened to be a rise from the bank to the first pontoon; and they agreed that the instability of the pontoons must be overcome in some more satisfactory way.

98. In order to investigate the subject thoroughly they ordered one of the experimental pontoons to have its central road-supporting beam lowered 3½ inches, and two of No. 6 pontoons to have their beams raised, one to correspond with the experimental pontoons as originally tried, and one with that now ordered to be altered. The objects of this experiment were:—

A. To find what effect was produced by the square sterns of the new pontoons as compared with the similar ends of the No. 6 pontoons.

B. To note the effect of lowering the points of support of the roadway.

99. The Committee were satisfied with the alterations made to the frames, and found that the new struts which were fitted in the room of the original ones, some of which had failed, were sufficiently strong. They afterwards inspected the new pattern trestle equipment.

100. On the 14th March three pontoons were put into bridge as follows:—

1.—A pontoon of No. 6 equipment with both ends rounded, and with its saddle raised to the same height as those of the new pontoons.

2.—Another of the same pattern with its saddle $3\frac{1}{2}$ inches lower.

3.—A new pontoon with its saddle lowered $3\frac{1}{2}$ inches.

101. Owing to the bad weather these pontoons could not be tried very fully, but enough was done on this and the next day to lead the Committee to the conclusion that if the new pontoon were to be lowered four or five inches, and widened as much as possible at the same time, it would be sufficiently stable.

102. The flotation of the new pontoons was carefully tested by loading them with sand-bags and Sepoys weighed just before being put on to the bridge. It was found that the new pontoon did not give the expected margin of safety with the weight of crowded infantry in fours by about $1\frac{1}{2}$ inch, which was attributed partly to error in calculating the area of the curved part, partly to excess of weight in the pontoon over what was expected, and partly to the thorough soaking it and the superstructure had received in the late rain.

103. Two pontoons were coupled together into the "heavy' form and placed in bridge for trial. As a preliminary to test the flotation, a load of Sepoys was placed on the bridge, and from this it was seen that the flotation of the heavy form was in excess of actual requirements as laid down. It was resolved to go further into this matter on the next day of meeting.

104. A bridge was afterwards formed across the canal with No. 6 equipment, consisting of 14 pontoons with two trestles at one end. Carriages weighted up to the 9-pounder and 16-pounder standards were passed over the bridge and the effect noted.

105. The Committee made a careful inspection of the advance and semi-permanent telegraph equipments, which were worked in their presence. The advance equipment is carried on wheeled

vehicles; and the semi-permanent equipments on elephants and other transport animals and vehicles as may be convenient. Scales of stores and transport were approved and ordered to be included in the report.

106. In the evening a pair of new pontoons were coupled into a pier for the heavy form of bridge, and were placed in a tank for experiments, being formed into bridge with double baulks and chesses, as proposed for service. A gun carriage loaded up to the weight of the 40-pounder B.L.R. was run on to the bridge, and with this load the margin of safety was observed to be $17\frac{1}{4}$ inches near the junction of the two pontoons forming a pier of the bridge. This margin was about $1\frac{1}{2}$-inch greater at the ends of these pontoons, which rose slightly owing to a little play being left in the couplings.

107. Afterwards, a load of men crowded together was placed on the bridge, with a view to testing the strength of the arrangement generally; and an alteration was ordered to be made in the mode of fixing the central saddle. The load carried was 9,240 lbs. on the single pier. The margin of safety was $16\frac{1}{2}$ inches near the junction with this load.

108. The pair of pontoons coupled into a pier of the heavy bridge having been again placed in the tank, with a doubled roadway as before, and the alteration ordered having been also made, a load of 11,230 lbs. was placed on the pier, which gave a margin of safety of $14\frac{1}{2}$ inches near the junction and 16 inches at the ends. After this trial, two diagonal struts were observed to be split at the end where they abutted on the angular corner piece at the bottom of the pontoon, the split being due to their shape at that point and showing that the mode of fixing requires alteration. The Committee thought that with this alteration the arrangement promised to be successful. It should, however, be further tried with several piers, in a current, before being finally adopted. The Committee decided to adjourn to Hurdwar to observe the bridging operations there in connection with the Hurdwar Fair.

109. The Committee then proceeded to Hurdwar in order to enable the new members to observe the mode of constructing bridges in a rapid current with No. 6 equipment, which is in charge of the 10th Company, Bengal Sappers and Miners, and closely resembles the pattern proposed for adoption by the Committee; and also with the trestle equipment approved.

110. In one of the bridges constructed at Hurdwar in a very

rapid stream, two piers of doubled pontoons were placed, and carried all the heavy traffic of the Fair there for a fortnight.

* * * * * *

The Committee then prepared, and on the 29th March, 1877, submitted the following report :—

REPORT.

1. An army operating in a country intersected by rivers, will usually require bridges of two kinds to be made for it ; namely, those to enable the advancing columns to overcome obstacles as they meet them, and those of a more permanent description intended to complete the lines of communication in the rear, after the main body has passed on.

2. The first, or "advance" class of bridge, must be sufficiently portable to accompany and even sometimes overtake the advance of the army, and to move over any ground and to any point accessible by the three arms ; while at the same time it must be so arranged as to be "formed" for use as quickly as possible, and to give as high a degree of safety as may be consistent with other requirements.

3. The "heavy" class does not as a rule require to be so portable, but must give much higher standards of safety, and must be capable of bearing such heavy and continuous traffic as is entailed by the passage of siege trains.

4. It is, of course, a great advantage if the requirements of both these classes of bridge can be met by the stores of the same equipment, and it is believed that the only satisfactory attempt in this direction has been made in England, where a heavy bridge is formed from the advance one merely by strengthening the roadway, the pontoons being considered to afford enough flotation for either form ; but the Committee think that this arrangement is not sufficiently powerful to meet the requirements of service in this country. They observe that the English pontoons in "heavy" bridge are open, and are depressed to within 6 inches of their coamings by siege artillery, and it seems certain that under such circumstances they would be swamped in the Indus at Attok, or in the Ganges at or near Hurdwar even in cold weather, while it is also certain that bridges might frequently have to be made in India under at least as unfavourable conditions as those presented by the two localities named, so that pontoons of much higher power for heavy bridge purposes than those of the home equipment, must be provided for India.

5. Another objection to the English system is, that its loaded carriages are much too heavy for advance work. It seems clear that if a pontoon train is to keep up with the advance of all arms, its carriages must not be greatly heavier than those of the lighter Field Artillery, and the Committee have accordingly agreed upon a maximum limit for the loads they recommend of 35 cwt.; being about the weight of a Field Artillery gun, the weight being calculated without that of men carried in each case. Now the weight of the English pontoon carriage complete, is about 39 cwt., and would be more if it were made up of stores of Indian materials. This is too high for service in India, and indeed, there seems to be a strong feeling at home that it is so for European service also (see the *Soldier's Pocket Book*, p. 306).

6. For these reasons the Committee do not recommend the adoption of the English pontoon system in its entirety for Indian service; but at the same time, as it comes nearer to what is wanted than any other with which they are acquainted, and as the objections above mentioned can be got over without (in their opinion) sacrificing any other material points, they have taken it as the basis of the system which they recommend, and they now proceed to describe the alterations which they think necessary to fit it for Indian service.

7. In the first place, it is intended to adhere to the plan of constructing the heavy bridge with the stores of the advance one, but to do this by coupling the advance pontoons in pairs, end to end, to form piers for the heavy bridge, as well as by strengthening the roadway, and thus to obtain a bridge of ample strength and flotation for any traffic likely to come on it. The pontoons should further be fitted with covers, removed when the former are required for use in ferrying, and should have one end of each made square to facilitate their being coupled together.

8. As regards the dimensions of the pontoons proposed, it has been found that the limits of width and length have been reached, and that if the height goes beyond a certain point the pontoons become unstable, and thus safety though apparently gained is sacrificed. As it is also considered that some reduction on the English standards of flotation is admissable, on account of the proposed closing of the pontoons, and the better arrangement for a heavy bridge, the Committee (taking the limits of length and width referred to) have fixed the height of their pontoon so that it will not be actually immersed by the greatest load when in advance bridge

(disorganized infantry crowded), while it will be sufficiently stable, and will afford ample flotation for ordinary loads in advance formation, and will give the standards of safety in heavy bridge which were laid down by last year's Committee. The dimensions proposed will be found in the description attached, together with the lines of flotation under different loads. The Committee recommend that a few pontoons of this description should be made and thoroughly tested, and that if they afford the flotation and stability expected, they should be adopted into the service.

9. The remainder of the bridge stores of the pontoon equipment need not differ in any important point from those of English patterns. A descriptive list will be found attached, with reasons for the departure from English patterns where any such are recommended.

10. With reference to the trestle equipment, the Committee recommend the adoption of the pattern in use at Roorkee. The same superstructure and carriages are used indifferently with this equipment and with the pontoons, and although in its ordinary form it will only carry the ordinary loads provided for by the advance bridge, it can be adapted for heavy traffic without difficulty.

11. The last important point in which it is proposed to modify the English system, is the arrangement of the equipment for transport. It has been mentioned that the carriages of the English equipment are too heavily laden for Indian service, and the Committee have laid down a maximum weight of 35 cwt. (without men) as the limit of a bridge train wagon complete. In accordance with this proposal, they recommend that three carriages should be allowed to every pair of pontoons with their stores, instead of one carriage per pontoon and stores, as in the home equipment. This arrangement will entail 36 bridge carriages for a train of 120 yards of bridge, but in those carriages almost all the accessory stores and materials will also be conveyed. The English equipment of the same length has only 25 bridge carriages, but as accessory stores are carried in extra wagons, a total of 31 is required. Thus, the increase proposed is not great, while the advantage of having lighter loads is important.

12. With reference to the amount of bridge train which should form one unit of equipment, the Committee would recommend the adoption of the British standard of 120 yards of bridge in the absence of any apparent reason against it. They would, however, suggest a departure from the home proportion of pontoon to trestle equipment,

and would propose 80 yards of the former to 40 of the latter to each unit, instead of 100 yards and 20 yards respectively, since they consider 20 yards of trestles too small a quantity of that class of bridge to be of much use. Such a unit should be the regular equipment of each of the pontoon companies of Sappers and Miners, and should be kept as complete as possible in transport, and all requisites for service. Thus, at Roorkee were there are two pontoon companies of Sappers, two complete units should be kept up, both of which should be provided with bullocks of the best quality permanently attached to the companies, as is done with heavy batteries, the drivers and others being placed on the same footing as to pay, &c., as in the Artillery.

General Description (Dated 20th April, 1877,) of Bridge Equipment Proposed.

1. The bridge is formed of "pontoons" or "trestles," kept at 15 feet central intervals by baulks, resting on transoms in the case of trestles, and on saddles laid on central saddle-beams in the pontoons.

2. In the "advance bridge" the pontoons and trestles are used singly; while in the "heavy bridge" the pontoons are coupled end to end in pairs, and the trestles are doubled in order to form supporting piers of sufficient power for siege artillery, &c.

3. The number of baulks used is five for the "advance bridge" and nine for the "heavy bridge;" they support chesses, which are kept in position by a riband on each side, racked down by rack lashings to the outer baulks, and leaving a clear roadway of 9 feet in the narrowest part. In cases where very heavy continuous traffic is expected, the chesses of the heavy bridge are doubled. In all cases the chesses are prevented from slipping laterally by chess pins, and a slight handrail is arranged by stretching a rope along each side of the bridge supported by oars placed in sockets in the pontoons.

4. The bridge is usually secured by means of anchors of the Trotman pattern, and cables of 3-inch rope.

5. The equipment is carried on 4-wheeled wagons, of which three are required for every two bays of the bridge; a bay being a pontoon or trestle with all the stores required to cover the interval between it and the next pontoon or trestle in bridge. These wagons are all exactly alike, although, of course, their loads differ, and when packed complete they do not exceed a maximum weight of 35 cwt. They are intended to be drawn by 6 horses or bullocks.

6. The buoyancy of the pontoons in "advanced bridge" has been calculated so that they shall be safe from submersion under an extreme load of 84lbs. per superficial foot of clear roadway, or disorganised infantry crowded together at the rate of about 55 men to 100 superficial feet. With this load the pontoon is immersed to within an inch of its deck, or three inches of its covered hatchway; while with the 16-pounder M.L.R. equipment fully horsed it has about one-quarter of its total flotation to spare (or nine inches of height from water to covered hatchway); and with infantry in fours crowded at a check (560 lbs. per foot run of bridge) it has about $7\frac{1}{2}$ inches margin from water to hatchway.

7. When two pontoons are coupled end to end in heavy bridge with a strengthened roadway they give a margin of safety, under the 64-pounder M.R.L. with limber, of about 14 inches; and under a load of 100 lbs. per superficial foot of roadway, of about $11\frac{1}{2}$ inches; while even under the extreme load of 133 lbs. per superficial foot of roadway they give a margin of $7\frac{1}{2}$ inches.

8. The pontoon is a boat with decked ends and partly decked sides, where six rowlock blocks are fixed. The undecked portion of the pontoon is $15' \times 4'\ 7''$, and is surrounded by coamings 2 inches high, over which covers are placed, with canvas flaps buttoned to brass studs on the sides of the coamings. The principal dimensions of the pontoon are as follows:—

Length on deck		22 feet.
Width	on deck	5 feet 7 inches.
	amidships	
	at bottom	4 feet 10 inches.
Depth	from deck	2 feet 2 inches.
	from top of coaming	2 feet 4 inches.

The pontoon differs from the English pattern in having one end square, and in being somewhat longer, wider, and shallower; the square end being given with a view to facilitating the coupling of the pontoons in pairs to form heavy bridge. The pontoon consists of six sets of framed ribs, connected by a kelson and side and bottom streaks, and covered with copper sheeting. There is a cleat at one end to secure the cable; the bottom is provided with two plug holes to let the water out, and there are 18 handles outside by which it is carried by hand and secured to the wagon for transport. There are three thwarts which support the saddle beam. The pontoons are coupled together for heavy bridge by means of iron tie-rods secured to the saddle-beams. The saddle-beams are thus thrown into compression, and the thrust is taken by a moveable beam placed centrally over the junction of the pontoons; the whole system becoming a double truss, and throwing the weight vertically on the pontoons, which are thus protected from undue strain.

9. A trestle consists of the transom, two standards, two keys, and two shoes, the same superstructure being used as with the pontoons. The transom is a teak beam, 17 feet by 9 inches by 6½ inches, with strengthened mortices at the ends to admit the standards. The standards are of teak, of three lengths, to suit various heights; namely, 18 feet, 13 feet, and 8 feet, and they are all 9 inches by 3 inches thick. They are pointed, and shod with iron at the lower ends, and fit into shoes 2 feet 9 inches by 1 foot 2½ inches by 3½ inches. The keys are pieces of teak, 2 feet by 3½ inches by 2 inches, which clamp the standards in the mortices of the transoms.

10. The saddle beam is a piece of teak, 11 feet 2 inches, by 6 inches, by 3 inches, with the top slightly rounded. It is permanently fixed in its place in the pontoon. The saddle is a framing of teak 11 feet 9 inches, by 6¼ inches, by 3 inches, which fits over the saddle beam, and has 5 sets of three-curved cleats to receive the ends of the baulks. There are handles at each end which also serve as cleats for cables and breast-lines.

11. The baulks are of teak, 15 feet 8 inches, by 6 inches, by 3¼ inches, provided at the ends with claws of ⅜-inch flat iron to prevent their slipping off their saddles. The chesses are teak planks, 11 feet by 12 inches by 1¾ inches. The ribands are identical in every respect with the baulks. The chess-pins are 7½ inches long, of ⅜-inch round iron, with an eye at top. They are strung in sets of 15 on ½-inch rope, and are inserted in ½-inch holes in the chesses outside the ribands and baulks. The shore-transoms are beams of teak used for the shore ends of the bridge, and are 13 feet 6 inches long by 6¼ inches by 6 inches. They are secured to the ground by pickets 3 feet by 2¾ inches, passing through 3-inch vertical holes in the transoms.

12. There are several points of difference between the superstructure described above and that of the home bridge. The saddle-beams of the home equipment are hollow, while those proposed for India are solid, and are better suited to the climate. This reduces the width of the beams and saddles. The baulks of the home equipment are halved at the ends, while those proposed are not so, and are considered simpler and better both for special and general purposes. The chesses of the proposed equipment are 1 foot longer

than the home ones, giving the same clear roadway, and more overlap and play at the ends. Special ribands are used in the home equipment, but the introduction of chess-pins in the proposed equipment enables baulks to be used for this purpose, and so simplifies matters.

13.—A unit of bridge train comprises stores complete for 80 yards of pontoon and 40 yards of trestle bridge.

M. T. SALE, CAPTAIN, R.E.
Secretary, R.E. Committee.

PAPER XIV.

FORTRESS WARFARE.

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A Lecture delivered in the Prince Consort's Library, at Aldershot, on the 6th December, 1875.

When, some little time ago, General Herbert asked me to give a lecture "about forts," I had a momentary misgiving when I pictured to myself the feelings with which a notice of a lecture on such a subject would be received by the majority of English officers. To the minds of most, the term "fortress warfare" naturally brings up a vision of Vauban's first system, and of those geometrical "*voyages en zigzag*," by which an enemy who did his *devoir* was always expected to approach a fortress—school exercises with which we are all painfully familiar. To some, indeed, it must have a more real, though hardly more agreeable signification, recalling the hardships and privations, the muddy trenches, and the "follow the Sapper" of twenty years ago, when we fought the Russians at Sebastopol, and learnt in our fortress warfare there how unprepared we were for war. But a little consideration reconciled me to the attempt, and led me to the belief that I should be able to put fortress warfare in such a light before you as to show that it is by no means altogether the Engineer's *spécialité*; and that, although it must always savour somewhat of slowness, yet it is far from being devoid of incidents calling for the display of enterprise, dash, and readiness of resource, as well as for those still higher qualities of good soldiers—patient courage, perfect discipline, and cheerful endurance of hardships; and, further than this, that fortresses exercise so great an influence on modern war, that no soldier can afford to neglect so important a branch of his profession as the study of fortress warfare.

establishment, and, at the same time, an intrenched camp ; and Metz, which is a depôt and magazine, a double bridge-head on the road between Paris and Berlin, and an intrenched camp.

The importance of a place may be so great for a particular theatre of war, or for a whole country, that possibly the result of the campaign, or even that of the whole war, may depend on its possession. In this case it must be so prepared by fortifications that a great part, or even the whole of the army, may be employed in its defence in addition to its own garrison. Of such a nature are the defences of Paris, of Antwerp, or the works designed for the defence of London-positions prepared for the home army to contend with the army the enemy is able to put into the field, and with which it is to be supposed the home army is not able to cope in unprepared positions. The struggle in this case is not for possession of the *place* so much as for the overthrow of the opposing *army*, and, therefore, it partakes more of the character of a fortified position than of a fortified place, although, in fact, the two must almost always, more or less, co-exist in a large fortress. It is necessary, however, to bear in mind clearly what is the object with which a fortress is constructed when either its attack or its defence is to be undertaken. When it is merely a *place* which is fortified, however necessary it may be that the place should be held or won, its fate will not decide the war, but is only one of the steps towards the decision, and it may be that a decisive battle elsewhere will entail its fall incidentally. When, however, the main army is to be dealt with in a fortified *position* it is the decisive struggle of the war, and the taking or holding of the place is a question of little importance compared with the result of the struggle between the opposing armies.

Thus, in the Crimea, the taking of Sebastopol would have had but little influence on the decision of the war had not the whole of the available forces of Russia been drawn into the struggle at that place, and it was, probably, a most fortunate mistake for us that we did not attempt to carry the place by storm when we first appeared before it. We have learnt after the event that most likely we should have succeeded; but to bring the war to a conclusion, we should then have been obliged to advance into the interior of the country, where our difficulties would have increased as those of the Russians diminished, and the result might have been very different from that which occurred, more by the exhaustion of Russian men and resources, by their long marches through dreary steppes to reach the theatre of war, than by the defeats we inflicted on them.

On the other hand, the fall of Belfort would not have had much influence on the general result of the war of 1870-71, while the fall of Paris and the defeat of Bourbaki's army entailed the fall of Belfort.

One more word on the general subject of fortresses appears necessary. If it be granted, as is undoubtedly the case, that armies must have secure depôts, magazines, and sources of supply, as well as hospitals, communications, and so forth, these must be guarded against hostile enterprises. The guards so employed are abstracted from the effective army in the field, and, if they are not aided by fortifications, they must be strong in numbers, discipline, and organization. But it is most important that a minimum of men, and these the least fitted for active service, may be able effectively to perform the duty, and this can only be obtained by the use of fortifications. Thus we come to the result that a well-considered system of fortresses, in which the number of points to be guarded is reduced to a minimum, so far from abstracting men from the field army, swells its numbers just in the proportion that fortifications enable us to diminish the strength of the guards otherwise necessary to secure the maintenance and supply of the army.

Having so far cleared our way by giving briefly the arguments from theory and from fact which justify the use of fortresses, and the general objects they are intended to fulfil, let us pass on to review the different phases of fortress warfare which may be developed in the course of a campaign.

For the assailant to invade the territory of the foe, it may be necessary to neutralise, in some way, the smaller or larger fortresses, which may bar his roads and interfere with the maintenance of his communications; he may have to meet and fight the enemy either in fortified positions or supported by fortresses, and, supposing the active army to be defeated, he may have to reduce all the strong points in the country which contain material of war, which cover beaten troops and allow them time to re-organise and rally, or which form a nucleus for the raising, training, and equipping of fresh armies, while his own fortresses secure his communications and sources of supply from a counterblow of the enemy, and, in case of failure, cover his retreat, and favour his re-organisation.

For the defender, fortresses gain time at the beginning of the war by delaying the progress of the enemy's march, they diminish the invader's active forces as he advances into the country, because he must leave troops behind to guard his communications against sorties from the fortresses he has not taken; they lend all the aid that can be derived from the combinations of art to help the weaker army in the decisive struggle, and in the manœuvres which may precede it. Supposing the defender's active army to be defeated, it may be preserved from destruction by the refuge afforded by an intrenched camp, and holding there to watch it a superior force of the enemy, time is gained for further combinations, or an honourable peace may be hoped for should the assailant not be prepared for the prolonged and arduous efforts necessary to reduce the defender's fortresses. Should, however, the war be carried on "*à outrance*"—as was the war of 1870-71—it becomes henceforward almost entirely a war about fortresses.

What, then, are the different ways in which a fortress may be dealt with?

1. It may be masked; *i.e.*, a sufficient force may be left to watch a fortress which is so near the lines of communication of an army as to endanger it by sorties, but not near enough to bar the way by its fire.

This duty may be performed by a force little, if at all, superior to that of the garrison in infantry, but it must be superior in cavalry and field artillery.

The general plan would be somewhat as follows:—

The infantry, with their artillery, take up a position between the fortress and the line to be covered, closing all the direct roads to the latter. Their outposts push on to within about a mile of the fortress, and watch all its issues on their side. The cavalry take up the line of outposts on the far side, and the main body of the cavalry is so posted that any attempt on the part of the cavalry in the fortress to sally out, and by making a wide circuit to get at, and destroy or injure any part of the line of communications, may be met and frustrated by a superior force of cavalry. At night the chain of sentries and vedettes is closed in as near to the fortress as possible. The cavalry, although unable to resist any sortie from the far side of the fortress, yet give timely notice of its being made, and of the direction in which the troops are moving. Bitsch and Toul were both masked during part of the war of 1870-71, and, at the former place, many encounters between the garrison and the force left to watch them took place from time to time, in which neither side had a marked advantage. At Toul, only one Landwehr regiment was left for some days to mask the garrison, who, however, supposed they were in the presence of a much larger force, and made no attempt to attack them, or to strike at the German line of communications.

The mere masking of a fortress, although it may prevent its garrison from sallying out to injure the communications of the other side, does not tend towards gaining possession of the place. Sorties for the purpose of foraging can be made with comparative impunity on the side which is only watched by cavalry, and relieving troops may also enter on this side, so that there is no probability of the garrison being starved out, nor is any pressure put upon them.

2. Should it be considered necessary to get possession of the fortress, one of the following methods must be resorted to:—bombardment by field artillery, surprise, storm, investment, bombardment by siege artillery, or regular siege. The first of these—bombardment by field artillery—ought not to succeed if the fortress is properly provided with bomb-proof accommodation, and if it does not enclose a large civil population. Even, in the latter case, if the Commandant be firm, and the place be tolerably large, the amount of injury inflicted by field artillery is so much less than might be expected, that no result ought to be obtained. A few fires will be started, which, with proper precautions, may generally be extinguished if energetically taken in hand at once, and there will be a certain proportion of casualties; but the experience of the late war goes to prove that the effect of field artillery is not so great as to produce an *immediate* result, and the supply of ammunition carried into the field is not sufficient to permit of the bombardment being continued so long as to produce that state of nervous horror which will demoralize the garrison and force a capitulation. If, however, the Commandant be incompetent, the troops inferior, and the civil population un-patriotic, such a course may succeed. As an example of a successful bombardment by field artillery, the case of Marsal, in 1871, may be cited. Marsal is a small fortress on the Seille, at the junction of the roads leading to Nancy from Strasbourg and Phalzburg. Seven field batteries, escorted by cavalry, were sent forward to reduce the place. The guns were placed on rising ground commanding the fortress, and it was summoned to surrender, but refused. Twenty-one rounds were then fired, when the white flag was hoisted. The garrison, however, was only a few hundred men, and there was no heart in the defence. Another example of a successful bombardment by field artillery occurred at Litchenberg, a small hill fort in the Vosges. It was attacked on the 9th of August by 2 battalions, $\frac{1}{2}$-squadron, 3 batteries, and a detachment of engineers. The infantry got cover close

to the place in the village on the west, and in a wood on the east, the cavalry kept up communication between the two battalions, and the guns opened fire from the hills on the west. The engineers, under cover of the artillery and infantry fire, got into the covered way, blew open a gate in the palisades, and examined the ditch, which they found too deep for escalade. The fire of the artillery produced so little effect, that after some hours the attempt was given up, and the troops were ordered to retire, leaving only a battalion and the cavalry to watch and mask the place. Just at this time, a large building burst into flames—the result of the previous artillery fire—and one battery was ordered back at 7 p.m. to open fire again. Upon this the Commandant immediately capitulated. He was, however, a very young officer, a second lieutenant, and his garrison were chiefly fugitives from Wörth, so that the inference must not be drawn from the historical fact that such a mode of proceeding *ought* to produce such an effect; but that under similarly unfavourable circumstances for the defence it may possibly succeed, and, therefore, may be worth trying.

Very different was the result in many other cases, notably at Toul and Phalzburg, The former was bombarded first by two field batteries, while six battalions of infantry made a demonstration of attack. The infantry were soon forced to retire with loss, and the guns only succeeded in producing one small fire, which was easily extinguished. A week later, 12 field batteries bombarded again without any result. After this, repeated bombardments by field artillery, in greater or less force, were endured by the garrison, who, so far from giving in, made repeated sorties, and did much harm to the Germans by the fire from their heavy guns and mortars. At length after six weeks' investment, the Germans placed 26 siege guns in battery, and bombarded with them for a whole day, when the French gave in, having fired away all their ammunition. It is to be specially noted that Toul had hardly any bombproofs, and that the garrison were mainly composed of Mobiles; but the Commandant was a good soldier, and infused his spirit into those under him. At Phalzburg, a bombardment by 60 field guns, which fired in all 1,800 rounds into the place, produced no effect. Here there were bombproofs and traverses for the garrison, as well as a firm Commandant, but there was also a considerable civil population, who bore with much heroism the sufferings and losses of this first great bombardment, and of several minor bombardments during some of the nights of the investment, which lasted four months, until want of food compelled the garrison to surrender the place.

The Germans did not generally use field guns for bombarding at extreme ranges, they preferred getting within a mile of the place, in order that the result of the firing might be carefully observed, and accurate fire concentrated on any building seen to be in flames, so as to prevent its being extinguished. But should circumstances of ground, &c., make it desirable, the range might be increased to two, or even three miles. As regards projectiles there was a difference of opinion. Some German artillery officers expressed a strong opinion in favor of incendiary shells, others considered the common shell sufficient.

Surprise is only likely to succeed when the garrison is known to be careless, and when some means of access into the place is known to exist, or some weak point in the fortifications where an escalade may succeed. The stories of our exploits in the Peninsula are so well known that I will not refer to them, although the Duke of Wellington more than once resorted to this mode of attack. The Germans were not very enterprising in this way during 1870-71, but they did make one unsuccessful attempt at Thionville, which they afterwards reduced by bombardment with siege artillery. The ground on which the attempt was made was information obtained from a reserve cavalry soldier who had been a resident in Thionville, and at the outbreak of the war was employed on the defences of the place. He found means to escape, and to return to Germany and join his regiment in time to take part in the earlier battles; but while at Thionville he had noticed that there was a ford through an inundation, which was the principal defence at one point in the *encéinte*. The plan was to assemble a sufficient force at hand during the night to endeavour to obtain possession of the place by effecting an entrance by the ford. It might have succeeded had not the Moselle risen, and made the ford impassable; but the enterprise was discovered by the French before it was put into execution, and probably success could only have been obtained by a great sacrifice of life. In this case the force employed consisted of all arms, and doubtless this was right, for, although the real conflict inside the place must have been carried out by the infantry, aided by a few engineers to act as guides and to overcome obstacles, and a few artillery to spike captured guns or turn them on the enemy, yet, in case of a failure and retreat, or of there being a force camped outside the fortress, the cavalry and artillery would have had their parts to play.

I would only farther allude to the absolute necessity of a well considered plan being arranged beforehand, and the exact duties of each body of troops concerned being clearly defined and made known to them in all such attacks. It was from the want of such pre-arrangement that we failed to reap the fruits of our successful entrance by surprise into Bergem-op-Zoom, the different columns of attack, having no orders what to do when they got inside the place, turned in opposite directions, and, becoming thus separated and confused, were beaten in detail and driven out by the French garrison.

The attack by storm may be preceded by bombardment, or may partake of the nature of a surprise ; but its essential features are a forcible entry by either destroying or surmounting the obstacles, *i.e*, battering down with artillery, or blowing in the gates, or escalading the walls, while the artillery and infantry keep down as far as possible the fire of the garrison. A well constructed permanent fortification should be secure against open attack by storm, or "*sturm-frei*" as the Germans concisely term it. It is only imperfectly constructed fortifications badly defended that can be reduced by such means, particularly when the attack is a surprise.

Should such an attempt be determined upon as necessary, owing to the importance of the place, and the insufficiency of means and time for other and surer methods of attack, it is all important, as above observed, to have a good plan, and to let all concerned know exactly what they have to do.

Previous experimental practice in any special method of overcoming obstacles, such as escalading, or throwing flying bridges over ditches, will be of great advantage. Probably we have all heard of the French "Malakoff drill"—the previous practice which enabled them by means of flying bridges to swarm into the works so rapidly, and which was the key to their success. Further, either by plans of the works, by information obtained from spies or deserters, or by actual observation, the nature and dimensions of the obstacles to be overcome should be as thoroughly as possible ascertained before the storm is undertaken. In the attack on Belfort the Germans attempted to take by storm the detached works on les Perches. They had obtained French plans of the fortress, which showed these only as field works, and relying on this information they advanced to the attack without any means of crossing ditches—arrived at the counterscarp they found that the ditches were cut out of the white limestone rock of which these hills are formed, and although a number of men jumped in they were unable to get out again, and were made prisoners by the French. One other condition, and a most essential one in all such undertakings, is the employment of a sufficient number of good troops. The Germans put it down as at least $2\frac{1}{2}$ to 3 times the garrison. Our failure at the Redan, on the 28th of September, 1855, is one of the many warnings against this miserable halting policy, as Sir John Burgoyne forcibly terms it, which fears to employ the means essential to victory, lest good troops should be sacrificed in a possible failure, and thus ensues failure, loss, and disgrace.

Blockade or investment is a slow but sure way of reducing a fortress, and the more mouths it contains the surer and quicker the process. It is also a necessary preliminary to a regular siege, and it may be combined with a bombardment by field or siege artillery. A force detailed for the investment of a fortress sends on in front by forced marches the cavalry and horse artillery, with whatever engineering means are organised for rapid movements to make the preliminary investment. Mounted riflemen would also be valuable for this service. Infantry transported in country wagons were sometimes employed by the Germans. The object of this preliminary investment is to drive in the cavalry outposts of the enemy, to cut their connection with neighbouring fortresses, or the seat of government by telegraph, rail, road, or water, to prevent supplies being taken into the place, and to prevent the destruction of bridges, &c., which favour the march of the investing corps. It is possible, of course, for the garrison to break this weak investment by infantry sorties, but, however active they may be, the cavalry investment is a serious evil to the garrison, and a valuable preliminary to the regular investment. One of its great uses is that by means of it a preliminary reconnaissance is made, existing maps are verified, advantageous camping grounds selected, and such a general knowledge is obtained of the environs, and of the state of the fortress and of the garrison, as will enable the general of the investing army to decide approximately on the positions to be occupied by the different corps in the investment, and to order their marches accordingly.

There was a case in the last war in which this preliminary investment was maintained for a considerable time. After the failure of the attempted *coup de main* on Thionville, and while the strength of the German armies was mainly devoted to dealing with the French armies at Metz, Sedan, and Paris, a regiment of lancers with a small detachment of engineers was left to invest Thionville. A four-horse coach was used to move the engineers rapidly from place to place to barricade roads, fortify buildings, &c., on the circumference of the circle watched by the cavalry. At night the posts were pushed in close to the place, at daylight they withdrew beyond cannon range, and by ceaseless activity and remarkable boldness and skill these 600 lancers, reinforced by 300 hussars for part of the time, and always aided by their coach-load of sappers, so imposed on the garrison, which consisted of 2000 regulars and 3000 Mobiles, with some cavalry and field artillery, that they held them inside their works for six weeks until the arrival of the investing corps.

I do not think a bolder feat, or one of which the German cavalry have more reason to be proud, was performed by that excellent branch of their army during the war, and I mention it to show how, even in fortress warfare, cavalry may often find full scope for their action; but I would take this opportunity of saying, that this is only one of the many cases in which a combination of a certain amount of field engineering, with ordinary cavalry duties is now called for.

In order that cavalry may be able properly to perform such duties one of two solutions must probably be adopted. Either cavalry officers and soldiers must be trained in field engineering, and must carry on their horses the necessary tools and appliances, or else they must have associated with them, when ordered on duties requiring engineering means and knowledge, a proportion of horse engineers—as they have already horse artillery—of such a body the Thionville sapper four-in-hand may be taken as the embryo or type; while the cavalry engineers in full bloom are to be found as yet only in the Austrian service, where, under the energetic direction of a genius and enthusiast in his profession, the system appears to have attained to great perfection, and to work well.

Whichever plan may be adopted in our service, I only hope that it may be thorough—no playing at engineering will meet the case. That our cavalry officers and soldiers have the ability to perform such work, no one can doubt for a moment, and if they take it up *con amore*, and if their training and equipment for such field engineering work as they may be called on to perform, be as perfect and as much a matter for the annual inspection by the General, as their training and equipment for ordinary cavalry duties now are, one can foresee a new and most interesting future for this arm; but if on the other hand, it be looked on as a *spécialité* in the hands of a few initiated officers and men, and in which Commanding Officers take no intelligent interest, one may safely venture to predict that it must inevitably prove a failure. Naturally being an engineer myself, my feeling is rather in favor of giving mobility to engineers, than of training and equiping cavalry to perform their duties. But I see, nevertheless, some advantages, particularly as regards unity of command, in the latter system, if it can be as thoroughly carried out as in the Austrian service, without impairing the efficiency of the cavalry for cavalry work.

But we must pass on to speak of more regular investments, which formed one of the most distinctive and most remarkable features of the War of 1870-71. Shortly before the outbreak of that War, a writer of note, whose work on the "Defence of States," is still a standard book, and whose genius has devised, and whose energy has mainly carried out, the modern system of the defence of Belgium —General Brialmont—devoted a chapter to prove that it was absolutely impossible to invest a great intrenched camp, and he cited Paris as an example of the value of such a fortress, impossible to invest, supremely difficult to reduce. I do not suppose that any one in Europe would have challenged the correctness of his conclusions before the stupendous events of 1870, except, indeed, those astute strategians at Berlin, who had evidently been able to realize beforehand, not only the possibility, but the comparative facility of such operations. And the flaws in General Brialmont's arguments are now evident enough. He based his conclusions, first, on the supposed impossibility of feeding, housing, and maintaining the enormous armies required for the purpose, at so great a distance from their own base, and for so long a time as would be necessary; secondly, on the supposed advantage the invested army possesses, owing to its interior position, secured from the concentric attack of the surrounding enemy by its forts, while it is able to issue in force at any point of the circle, and to attack suddenly and unexpectedly with greatly superior forces, thus having always the power of the initiative, and of being the stronger at the point attacked, the acknowledged main elements of success in war.

The question of supply was solved by the Germans, by the skilful use of railways, and of their Etappen system, of which I will say no more, as Lieut.-Col. Home discusses this subject.

But the question of exterior *versus* interior position is so interesting and important that I must devote a few minutes to it.

The universally accepted laws of strategy teach us, that when opposing armies in several distinct fractions are manœuvring at a considerable distance apart from one another, that army whose fractions can most readily combine to attack one of the isolated fractions of the other, has the immense advantage always claimed for interior compared with exterior lines or positions. When, however, the armies are so near that the whole of one army is menaced or attacked by the fractions of the other army, within supporting distance of one another, the concentric attack of the armies on exterior lines, probably succeeds. The moment we pass from the realm of strategy to that of tactics, the advantages formerly appertaining to the interior or central position, have passed over to the other side. Should the army in the interior position, however, be supported by the fortifications of an intrenched camp, the question is considerably altered, for, in the first place, the concentric attack of the exterior armies, even if very superior, cannot strike home, being arrested by the fortifications; and if there be a near approach to equality between the opposing armies, that which is in the interior position, not only is unattackable by the other, but under certain circumstances it has a great opportunity of inflicting a crushing defeat on the army outside, because the forts protect its rear, or its flank in offensive movements, and its interior position, and presumed good and short communications enable it to manœuvre so much more rapidly than the army outside, as to be always stronger than the force opposed to it, whenever it strikes outwards.

All this is still true as it was in former days, but the great power of long resistance to attack in front by greatly superior forces, conferred by improvements in fire arms, here comes fully into play. The investing army presents an unbroken front with no flanks to be turned, and wherever the invested force attacks, it must always itself be outflanked, and be under the necessity of making a frontal attack. The question then arises how many men can be employed with advantage, per mile of front, in a purely defensive action. Whatever this number may be, if the investing force can only dispose of so many troops all round the circle, with reserves in convenient positions to be brought up to reinforce any part of the line which may be hardly pressed, the task of the army inside, in any attempt to break out, becomes extremely difficult, for, whatever numbers it may be able to bring to bear on any part of the circumference, no more men can be employed in the shooting line in front than are opposed to them—in fact, not so many—as, on whatever extent of front the attack be made, the front of the investing defender must extend beyond it on both flanks. In the days of shock tactics, columns of attack would burst through the thin line, but in these days of fire tactics, the thin line is too strong for the column. All that the attack can do is to melt away the line at the point of attack, as it also melts away itself by the fire action on both sides, and being able to supply the losses of its own front line without stint, while the investing line has only weak reserves at hand; in course of time a gap is made, and the stream pours through. But in the first place the *time* required to overcome the resistance of the investing line at any point is now considerable, and a well arranged investing line consists of three concentric circles, the outpost line intended to stop small sorties, and to delay great ones, then the main position, and finally, rallying positions in rear. The resistance offered at these successive points must always cause great delay; if they have been fortified, the time required to force them, whatever numbers may be employed, is greatly increased, and, during all this time, reserves are brought up from the flanks and rear. Moreover, should the invested troops succeed in forcing their way through, and break out, it will be only to find themselves in the disadvantageous position of being attacked on both flanks and in rear, without the support of fortifications, and without the possibility of taking any train of supplies with them, until the investing force has been completely beaten and driven away.

It is true that successful sorties in force may be of great value to the defence. When they have a definite aim, such as to gain some vantage ground, which will greatly extend the investing line, for instance, the high ground commanding the passages of the Moselle, at Malroy, above Metz, or to destroy or get possession of the depôts of the investing force, for instance, the railway station at Courcelles, which would have fallen into the hands of the French, had their sortie of the 31st August been carried out to its legitimate conclusion, however imperfectly commenced; or finally, to save a portion of the invested force from reduction by famine, and to prolong the resistance of the remainder; as, for instance, had Bazaine broken out with two of his corps northwards, and gained Thionville, and thence, if necessary, the Belgian frontier, so saving part of his army, and by diminishing the number of mouths, enabling the rest to hold out longer.

We see then the present state of the question, as regards the value of intrenched camps or permanent fortified positions, to be this. For their owners, primarily, the protection of an army unable to cope with the enemy in the field, obliging him to invest them with a force considerably larger, and so neutralising this force during the period of the investment. In a secondary way, giving the invested force a chance of obtaining, at least, partial success, by large sorties, particularly at the beginning of the investment, if it be not skilfully and carefully conducted. But on the other hand, although the long ranges of rifled guns keep the invester at a greater distance than formerly, railways and rifled breechloading small arms enable him to maintain the enormous armies required for the purpose, and to hold the long line of investment with comparatively weak forces.

Let us review for a few minutes the tactics of both sides in the war of investment. An investment can only take place when the investing is so much stronger than the invested side, that the armies of the latter cannot keep the field in the presence of the full strength of the former, and have either been driven away from a fortress which is defended by its proper garrison, as was the case at Belfort, or have been forced to take refuge in it, as the result of a lost battle, as at Metz ; or it may be simply the result of the evident superiority of one side forcing the other to take refuge behind fortifications, as would probably be the case at Antwerp, were Belgium to be invaded by France or Germany. The investment of a fortress which does not at the same time shelter an army, and thus become a fortified position, is evidently easier than the latter, and the tactics of attack and defence in the two cases will be somewhat different.

In the defence of a great fortress by its own garrison, it is clear that the first endeavour should be to obtain information of the enemy's movements, and to check his preliminary investment; in both of these duties the cavalry have their *role* to perform. The investor, on the other hand, with a superior force of cavalry, forces the invested cavalry within the line of infantry outposts which will probably be 1000 yards in advance of the forts.

Should an army be sheltered by the fortress, the preliminary investment will probably be impossible, as a considerable force of all arms would be maintained outside the girdle of forts, to prevent any such attempt, and to harrass and obstruct the advance of the investing army.

The mode of bringing up the troops for the investment, and of moving them into the positions they are to occupy, requires careful forethought, if an army is to be enclosed ; as any unwise division of the forces during the process of filing into their positions, might be taken advantage of by the army to be invested with disastrous results to the investor. As in all military operations, no exact rules can be given, because circumstances vary infinitely ; but the general idea of such an operation is that the different corps of the investing army advance in concert, on the same side of the fortress, the advanced guards of the troops deploy, and drive in the enemy's outposts until they come under fire of the fortress artillery, then the advanced guards take up the best positions they can to resist a counter attack, while the main bodies move up into their appointed positions. Each successive corps in its encircling march, moves in rear of, and covered by, a corps already in position; thus the deployment is continued probably from both outer flanks of the roads by which the general advance has been made, until the forces join hands on the far side. Probably, however, the operation will not be completed without a general action, in which the force to be invested may derive the greatest assistance from its fortifications, and the would-be investor may find the task too hard for him.

Supposing, however, that the circle is completed, in order that unity of design may exist in the investing arrangements, an engineer reconnaissance is made as early as possible, completing, it may be, a previous cavalry reconnaissance, and on the information and recommendations so obtained, the General commanding issues the orders for the positions to be occupied by each corps. These positions may vary somewhat in extent according to the character of the terrain, and the comparative strengths of the forces inside and outside the fortress. As before mentioned the investment is arranged in two or three, or even more, concentric lines. The outpost line can seldom be nearer than from 1 mile to $1\frac{1}{2}$ miles from the forts, the main line about $2\frac{1}{2}$ to 3 miles, the rallying position about a mile farther to the rear; the general line of the main positions is indicated by the General commanding, but the details are left to corps commanders. The extent of each section will vary between the allowance of 3,000 to 7,000 infantry per mile. At Metz, where a regular army was enclosed, an average of about 7,000 infantry per mile, in addition to cavalry and field artillery, were considered necessary by the Germans, but in some cases the number was as high as 10,000, in some as low as 5,000. At Paris, the average was a section of about 5 miles to an Army Corps, or, 25 battalions, with 14 batteries, and 8 squadrons; giving from 4,000 to 5,000 infantry to the mile. The ordinary number of troops required for the investment of a fortress, *not* enclosing an army, is generally laid down at about three times the garrison, and this would generally suffice. Take Metz as an example, the perimeter of the entrenched camp there is about 15 miles, the diameter about 5 miles; the main position of an investing army must be about $2\frac{1}{2}$ miles outside this, or be a circle with a diameter of 9 or 10 miles, and a circumference of 25 or 30 miles. Practically the German positions extended for 27 miles.

The garrison the Germans allot to this fortress is 40,000 men; three times 40,000 men = 120,000—the number that would theoretically be required to invest them. These 120,000 distributed over 27 miles, would give an average of about 4,500 men to the mile; which probably is a minimum, if regard be had to the necessary fatigue and exposure of the men. If on the other hand, an army of 60,000 men were taking refuge in the entrenched camp, bringing up the total to 100,000, the investing corps must be stronger, but not 300,000, which would be in the same proportion as before. It would, no doubt, be necessary to increase the force to about 5,000 men to the mile, which would give a total of about 135,000; while, should the army taking refuge be 120,000 men making a total of 160,000; (a little less than the French had in Metz) the investing corps need not be much superior to it. Even the maximum of 7,000 men to the mile would only bring up the numbers to 190,000.

The principle involved, has already been alluded to, only a certain number of men per mile can be employed to shoot at one time; if these exist with sufficient supports and reserves to fill up casualties, and recover ground lost by any failure on the part of the investing troops, *no* numbers that can be massed to attack in front, are of any avail. It is indeed almost proved by the events at Paris, that an average of 5,000 men to the mile on the investing line, is sufficient to keep in *any* number that may be inside, even considerably superior to their own, as was the case towards the end of that investment, but the indifferent character of the troops inside, makes it somewhat hazardous to argue from this example.

On these principles, then, the necessary strength for an army of investment is determined, and the line apportioned out amongst the different corps composing it. Wherever natural obstacles bar the egress of the troops inside, these may be watched mainly by cavalry, as the loops of the Seine were, below Paris. The field artillery is placed generally, in the main position, commanding all the roads leading out of the fortress, and the open ground where troops may be massed for attack. Occasionally some guns may be further advanced, but as they cannot contend with the fortress artillery, it is better to keep them out of their effective range. The duties of the troops are so arranged that they take the outpost duty in turn.

In the investment of Paris, each army corps had one division on duty each week, the other off duty; and of the division on duty, one brigade was in the outpost line, the other in reserve, in the main position on alternate days. The artillery and cavalry were generally in reserve, one or two batteries, and a squadron being always on duty in the main position.

The works to be performed by the troops, are, first the fortification of the outpost line, then that of the main position, and the improvement of communications of all sorts, the hutting of the troops on duty, and finally the preparation of the rallying positions. It is evident that the method pursued at Paris, where the positions at first assigned to the various corps were not altered throughout the duration of the investment, is very much to be preferred to the plan adopted at Metz, where the troops were continually being moved, according to the varying circumstances of the war, and the supposed intentions of the French, and which resulted, not only in very unnecessary fatigue and annoyance to the troops, but, in fact, was the main cause of the French success on the 31st August; as the part of the line they attacked, was then almost denuded of troops, which had been moved to meet an expected attack on the west. In the case of a strong investment, no reserve corps appear needful; but in the case of a weak investment, of say, only 3,000 men to the mile, it would appear advisable to have a strong reserve to every two or three sections of the investing line, that is to ten or fifteen miles.

The character of the outpost line would generally be as far as possible, a continuous line of obstacles, under direct and flanking infantry fire from the infantry posts at all the strong points in it; piquets and sentries in front of this line, sheltered as well as possible, and always altering their position at night, and patroling well to the front. In the main position, only such fortifications as will not interfere with the counter attack, which must be delivered to regain the outpost line, should the enemy succeed in forcing it.

Let us glance now at the duties of the invested; whether it be a fortress with only its proper garrison, or whether an army be taking refuge there also, the general plan assimilates to that of the investor. The circumference to be defended is divided into sections entrusted to corps, divisions, or brigades, who are responsible for their own sections, and in each of which there is a proper rotation of duty, special garrisons being always detailed for the forts. Without entering into any of the details of the defence, I would only allude to the two subjects of outposts and sorties. The distance in advance of the forts, at which the defenders can maintain their outposts, depends, of course, on many circumstances ; but unless these be very unfavourable to the defence, they ought to be on an average 1,000 yards in advance, as long as the artillery in the forts is unsilenced, and in many cases they may be still farther to the front; they should not be connected by obstacles wherever sorties are intended, as these would be hindered by such accessories, but between the forts in the main position the line should be made continuous by fieldworks, openings being left close to the forts, and this line of fieldworks would be the eventual position for the main artillery defence, in case of a siege. Thus the outposts act as an outer line of detached forts, while the forts connected by fieldworks, form an outer *encéinte*, and the enemy is pushed out one step farther from his object. Small sorties should be made systematically, at night, in all directions at irregular hours so as to keep the investing troops on the alert, and to weary them out.

Sorties in force should only be made for definite objects as before mentioned, and the plan should generally be somewhat as follows : The troops intended for the attack, should be assembled during the night, as near to the point of attack as possible, secretly and noiselessly. The advanced guards attack, and carry by surprise the investing outposts before daybreak, and followed closely by their supports and reserves, push on as rapidly as possible to the main position, so as to traverse the zone of artillery fire, and to gain all the ground possible before daybreak ; then a combined attack, fully supported by artillery on the enemy's position to be won, and on the positions right and left of it, for it must be borne in mind that reinforcements for the part of the line attacked are most quickly obtained from the adjoining corps, and that, consequently, if the real attack be made, let us say, northwards, the false attacks should be made to the east and west, rather than to the south, although a preliminary small sortie to the south might serve to mislead the enemy, who would probably hear some sounds of movement, and be somewhat on the alert.

Points won must at once be intrenched, of which we have a successful example in Ladonchamps—won, intrenched, and permanently held by the French in one of their sorties from Metz.

Should an army be forced by inferiority, to take refuge in an intrenched camp, it may have a great opportunity of defeating a superior force, by fighting in its prepared position, where it has everything in its favor, and can but be invested, if defeated.

The possibilities of successful manœuvring for an inferior force, aided by a permanent entrenched camp, have never yet been exemplified; but there is here, a great field for skilful generalship, and we may expect to see its results in any future European war; but when once shut inside the fortified lines of investment, an army has little hope of escape, unless aided from without.

As regards this external aid, an investing force used to protect itself by lines of circumvalation; but such a method would be quite unsuited to modern requirements. Relieving armies must be met and beaten at a distance from the fortress by a covering army, and the lines of communication for supply of the investing army, must be protected. Sometimes several such covering forces may be needful, as at Paris in 1870; by the free use of cavalry, and of the electric telegraph, it has become possible to combine and direct the action of these different armies, so as to neutralise any efforts at relief, unless made in overwhelming force, and with great skill, the covering armies occupying, strategically, interior positions with reference to the relieving armies.

Our time draws to a close, and I must confine myself to a few remarks on bombardment and sieges.

The humanity of the former mode of proceeding has been doubted and its efficacy has been sometimes over-rated. There can, however, be no question that a fortified place must be subjected to the rigours of war. It is usual at the beginning of an investment, to allow any civilians who may desire it to leave the place—after that they must stand or fall with it; and as regards actual loss of life, the statistics of the last war seem to prove that the famine and privation endured during a long investment, are far more destructive to the inhabitants of a town than a bombardment. The theory of a bombardment is that the constant bursting of shells, and the conflagrations, deaths, and wounds caused by them, produce such a state of horror and nervous terror, that human nerves cannot bear the tension beyond a certain time, and so a capitulation is forced on the Governor by the civil population. The bombardment of a fortress which does not take effect upon a town enclosed, and in which the garrison have sufficient bomb-proofs, produces no result. But the regular bombardment by siege artillery, of one of the old fortresses enclosing a town, was a mode of attack which proved irresistible in the last war. The noteworthy points are the slow rate of fire maintained by the

Germans in such operations—not more than four rounds an hour by day, and one by night, from each gun; and the excellent system of siege artillery, with all its appliances, and organisation of men and material, which exists in the German service. At present we have nothing to compare with it.

A siege becomes necessary when none of the easier methods are sufficient to reduce a fortress. No good modern fort or fortress ought to be reduced without a siege. We are still without examples of a modern attack on a good modern fortress—and the details of a siege are too technical—too much the acknowledged province of the artilleryman and the engineer to come within the scope of the present lecture—but I will just indicate the general principles of the operation in its modern form; first comes the investment, and while the siege train and the special siege corps are being brought up, preparations are made for the intended operation as far as possible by the collection of siege materials—gabions, fascines, timber, &c., in which all the troops off duty are employed. The choice of the front for attack, is now mainly influenced by the means of transport; and no large inland siege can be undertaken without the aid of a railway to transport the enormous quantities of ammunition required. At Strasbourg, more than 150 tons were fired away every day. The old calculations for the strength of a besiging army hardly hold good now, and the mode of attack has altered considerably. The investing force is the primary consideration; the siege corps proper strengthens the investment on the side to be attacked, and has attached to it a sufficient proportion of garrison artillery and engineers, to work the siege guns, and to make the batteries, saps, and mines. The siege proper opens by an artillery attack with siege guns in battery, at ranges of from 3,000 to 4,000 yards, to silence the fire of the fortress, and to enable the outposts of the investment, under cover of which the batteries were built, to drive in those of the defender, and the first parallel to be established. This would probably be about 800 yards from the place, and is the first infantry position from which marksmen can fire accurately at the defenders if they show themselves. A second artillery position is then prepared at from 1,000 to 1,500 yards from the place; and a more complete effect is produced on the defences. The advance to the fortress is then carried forward under support of these batteries, much in the same manner as formerly, except in the details of saps which I will not here discuss.

The formation of breaches and the silencing of flank defences of the ditches, will now be effected in most cases by curved fire from batteries not nearer, probably than 800 yards. Batteries on the crest of the covered way would be so difficult to make, arm, and work, under the close fire of modern rifles, that probably mines will be used for the close attack, when the necessary results cannot be obtained by artillery fire.

In the defence the great feature of modern fortress warfare, is the constant construction, and unexpected opening of new batteries between the forts; to silence these has been found much more difficult than to keep under the fire from the forts themselves. At least two of the detached forts must be taken, and the adjoining ones silenced before the interior *encéinte* can be attacked. If this be sufficiently far from the object to be defended or gained, to make a bombardment from the position of the forts unlikely to produce the desired effect, a second siege must be commenced to get into the *encéinte*; but in most existing fortresses, when once the detached forts have been taken, a bombardment will complete the work, as the vital point is then within range.

I have now touched briefly on a few of the most important features of fortress warfare, and however imperfectly my task has been performed, I trust that it will be admitted, as a fair conclusion, that this special phase of fighting holds at least as important a place in modern warfare as it has always had in former times, and that a thorough knowledge of the use of fortresses, and of the ways in which they may be employed or neutralised, is most essential to officers of all branches of the service, while to statesmen and strategists, generals and their staff, they present some of the most interesting and difficult problems of war. To artillerymen and engineers, the subject is, of course, vitally important, and the details in many points are still imperfectly worked out in our service; notably, I may venture to mention, good carriages for siege guns, and for garrison guns to be served on open ramparts, which will do away with the old embrasure, now obsolete, owing to the accuracy of modern firearms.

HENRY SCHAW,

LT.-COL., R.E., AND BT.-COL.

the ditches, will now be effected in about as costly covered fire; as batteries not nearer, probably, than 600 yards. Batteries on the crest of the covered way would be so difficult to make, arm, and work, under the close fire of modern rifles, that probably mines will be used for the close attack, when the necessary breaches cannot be obtained by artillery fire.

"In the defence the great feature of modern fortress warfare is the constant communication, and unexpected opening of new batteries between the forts; to silence these has been found a work more difficult than to keep under the fire from the forts themselves. At least two of the detached forts must be taken, and the adjoining ones silenced before the interior enceinte can be attacked. If this be sufficiently far from the object to be defended or gained, to make a bombardment from the position of the forts unlikely to produce the desired effect, a second siege must be commenced to get into the enceinte; but in most existing fortresses, when once the detached forts have been taken, a bombardment will complete the work, as the vital point is then within range."

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PAPER XV.

FORMULÆ FOR

SUSPENSION BRIDGES.

BY LIEUT. F. R. DE WOLSKI, R.E.

IN Appendix B to Captain Fraser's paper on Suspension Bridges, in *The Professional Papers of the Royal Engineers*, Vol. XXII., will be found the results of experiments to ascertain the tension and deflection of a heavy rope, loaded with a weight at its centre. On referring to Table II. of these experiments, it will be seen that the calculated stresses are considerably in excess of those actually recorded by the dynamometer. The formula employed in the calculations—

$$\text{Tension at either pier} = \tfrac{1}{2}\sqrt{L^2 + \frac{a}{4\,d}\,(L + W)^2}$$

where L = total load on rope,
,, W = concentrated load at centre,
,, a = span,
,, d = droop of rope due to its own weight only,

assumes that the horizontal tension caused by a concentrated—in addition to an uniform—load is equal to that which would be produced by an uniformly distributed load of twice the concentrated load added to the uniform load, the tension at the piers being the resultant of half the actual total load and this horizontal tension. This distribution of the load is applicable to beams; it does not hold good in the case of a span of rope.

The object of this paper is to show that the problem admits of correct solution in a form convenient for calculation. The only assumption made is that in the ordinary forms of suspension bridges the proportion of droop to span is so small that the weight of the rope may be treated as an uniform load, distributed along a horizontal line. The curve assumed by the rope will then be parabolic.

The problem to be solved, in its simplest and most generally useful form, may be stated as follows :—

Given the span, droop, and weight of a heavy, inextensible rope, suspended between two points in the same horizontal plane, to find the tension at the points of support, and also the depression of the rope, when a given load is hung from its centre. (See *Diagram* 1.)

The concentrated load W at the centre of the rope ADB, causing it to assume the position AGB, may be replaced by its own weight of the same rope. Let JG be this length of rope. Bisect it in E. Then E is the lowest point of a parabola MJEGOB, in which the tensions are the same as those in the curve AGB. Further, as the rope is inextensible and of fixed length, the curves DB and GB are of equal length.

$$\text{EG} \times w = \text{EK} \times w = \frac{\text{W}}{2} \text{ (by hyp. and const.)}$$

$$\therefore \text{EK} = \frac{\text{W}}{2\,w}.$$

Similarly, $$\text{EF} = \text{EK} + \text{KF} = \frac{\text{W}}{2w} + \frac{a}{2}.$$

$$\therefore \text{EF} = \frac{\text{L}}{2\,w}.$$

Again, $$\text{BF} : \text{GK} :: \text{EK}^2 : \text{EF}^2.$$

$$y : y' :: \text{W}^2 : \text{L}^2.$$

$$y' = y \times \frac{\text{W}^2}{\text{L}^2}.$$

Now length of curve $\text{BD} = \dfrac{a}{2} + \dfrac{4\,d^2}{3\,a}$,

and „ „ $\text{EG} = \text{EK} + \dfrac{4\,y'^2}{6 \times \text{EH}}$,

„ „ „ $= \dfrac{\text{W}}{2\,w} + \dfrac{4\,y^2\,w\,\text{W}^3}{3\,\text{L}^4}.$

But „ „ $\text{EB} = \text{EG} + \text{GB} = \text{EG} + \text{DB}.$

„ „ „ $= \dfrac{\text{W}}{2\,w} + \dfrac{4\,y^2\,w\,\text{W}^3}{3\text{L}^4} + \dfrac{a}{2} + \dfrac{4\,d^2}{3\,a}.$

Also „ „ $\text{EB} = \text{EF} + \dfrac{4\,y^2}{6\,\text{EF}}.$

„ „ „ $= \dfrac{\text{L}}{2\,w} + \dfrac{4\,y^2\,w}{3\,\text{L}}.$

Equating the values of EB, we get,

$$\frac{W}{2\,w} + \frac{4\,y^2\,w\,W^3}{3\,L^4} + \frac{a}{2} + \frac{4\,d^2}{3\,a} = \frac{L}{2\,w} + \frac{4\,y^2\,w}{3\,L}.$$

$$y^2\left\{\frac{4\,W}{3\,L} - \frac{4\,w\,W^3}{3\,L^4}\right\} = \frac{a}{2} + \frac{4\,d^2}{3\,a} + \frac{W}{2} - \frac{L}{2\,w}.$$

But

$$\frac{W}{2\,w} - \frac{L}{2\,w} = -\left\{\text{EF} - \text{EH}\right\} = -\frac{a}{2},$$

$$\therefore\ y^2 \times \frac{4\ W}{3}\left\{\frac{L^3 - W^3}{L^4}\right\} = \frac{4\,d^2}{3\,a};$$

$$y^2 = \frac{d^2\,L^4}{w\,a\,(L^3 - W^3)};$$

$$y = \frac{d\,L^2}{\sqrt{w\,a\,(L^3 - W^3)}};$$

But

$$y = y' \times \frac{W^2}{L^2};$$

$$\therefore\ y' = \frac{d\,W^2}{\sqrt{w\,a\,(L^3 - W^3)}}.$$

Depression DG $= y - y' - d.$

$$\text{,,} \quad = \frac{d\,L^2}{\sqrt{w\,a\,(L^3 - W^3)}} - \frac{d\,W^2}{\sqrt{w\,a\,(L^3 - W^3)}} - d.$$

$$\text{,,} \quad \text{,,} \quad = d\left\{\frac{(L^2 - W^2)}{\sqrt{w\,a\,(L^3 - W^3)}} - 1.\right\}$$

$$\text{,,} \quad \text{,,} \quad = d\left\{\frac{L + W}{\sqrt{L^2 + LW + W^2}} - 1\right\} \quad \ldots\ldots\ldots\ldots [1].$$

In the triangle of forces BNF,

$$\text{BF} : \text{NF} :: \frac{L}{2} : \text{H}$$

$$y : \frac{L}{4\,w} :: \frac{L}{2} : \text{H}$$

$$\therefore\ \text{H} = \frac{L^2}{8\,w\,y} = \frac{L^2\sqrt{w\,a\,(L^3 - W^3)}}{8\,w\,d\,L^2}.$$

$$\text{,,} \quad = \frac{\sqrt{w\,a\,(L^3 - W^3)}}{8\,w\,d} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2].$$

Tension at either pier $= \text{T} = \sqrt{\text{H}^2 + \frac{L^2}{4}}.$

$$\text{,,} \quad \text{,,} \quad = \sqrt{\frac{w\,a\,(L^3 - W^3)}{64\,w^2\,d^2} + \frac{L^2}{4}}.$$

$$\text{,,} \quad \text{,,} \quad = \tfrac{1}{2}\sqrt{\frac{a^2}{16\,d^2}\ \frac{(L^3 - W^3)}{(L - W)} + L^2}.$$

$$\text{,,} \quad \text{,,} \quad = \tfrac{1}{2}\sqrt{\left\{\frac{a}{4\,d}\right\}^2 (L^2 + LW + W^2) + L^2} \ldots [3].$$

The formula used by Captain Fraser, when put in the same form is :—

$$\text{Tension} = \tfrac{1}{2}\sqrt{\left\{\frac{a}{4\,d}\right\}^2 (L^2 + 2\,LW + W^2) + L^2}.$$

The formula for the length of rope, from which the ordinates are calculated,

$$s = a + \frac{8\,d^2}{3\,a}.$$

gives a result which is an extremely close approximation to the true length of the catenary. The error in length is only $\frac{1}{9720}$th of the span (less than the true length) of a catenary with a droop of $\frac{1}{12}$th, and $\frac{1}{3240}$th of the span (greater than the true length) for a similar parabola.

Example on page 182, Vol. I., Part 3, *Instruction in Military Engineering.*

$$W = 7{\cdot}5 \text{ tons.}$$

$$a = 200 \qquad w\,a = 8{\cdot}0 \text{ ,,}$$

$$d = \tfrac{1}{10} \times 200 = 20 \qquad L = 15{\cdot}5 \text{ ,,}$$

$$\text{Tension} = \tfrac{1}{2}\sqrt{\left\{\frac{a}{4\,d}\right\}^2 (L^2 + LW + W^2) + L^2}.$$

$$= \tfrac{1}{2}\sqrt{\frac{25}{4}\,(240 + 116 + 56) + 240}.$$

$$= \tfrac{1}{2}\sqrt{2820}.$$

$$= 26{\cdot}56 \text{ tons.}$$

The formula in the manual, the same as that used by Captain Fraser, gives :—

$$\text{Tension} = \tfrac{1}{2}\sqrt{\frac{25}{4}\,(240 + 232 + 56) + 240}.$$

$$= \tfrac{1}{2}\sqrt{3546}.$$

$$= 29{\cdot}8 \text{ tons.}$$

The difference is $3\frac{1}{4}$ tons, or $12^{\circ}/_{\circ}$ in excess.

$$\text{The depression at centre} = d\left\{\frac{L + W}{\sqrt{L^2 + LW + W^2}} - 1\right\}$$

$$= 20\left\{\frac{15{\cdot}5 + 7{\cdot}5}{\sqrt{412{\cdot}75}} - 1\right\}$$

$$= 20 \times \frac{2{\cdot}7}{20{\cdot}3}.$$

$$= 2{\cdot}66 \text{ feet.}$$

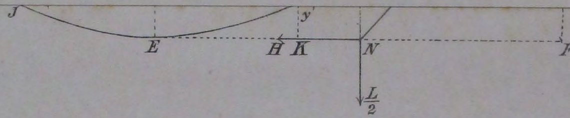
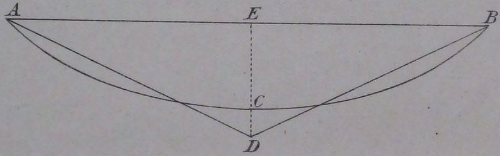


Diagram 2.



Application of Formulæ 1 and 3 to Table II., page 64, *R.E. Professional Papers*, 1874, Vol. XXII.

$$a = 127. \qquad w\,a = \frac{127 \times 40{\cdot}6}{6} = 860 \text{ lbs.}$$

No. of Experiment.	Dip of Cable.	Depression.		Concentrated Load.	Tension of Rope.		Percentage of error.
		Measured.	Calculated.		Measured.	Calculated.	
VIII.	$\frac{1}{10}$th	1·28	1·350	406	1848	1991	7·7%
IX.	,,	1·72	1·722	910	2815	3080	9·4 ,,
X.	$\frac{1}{12}$th	1·00	1·104	406	2397	2352	1·8 ,,
XI.	,,	1·43	1·432	910	3725	3649	2·0 ,,
XII.	$\frac{1}{16 \cdot 7}$th	1·70	0·940	610	3780	3955	4·1 ,,
XIII.	,,	1·80	1·031	910	4424	5006	13·0 ,,
XIV.	,,	2·25	1·055	1022	4648	5408	7·7 ,,

In Experiments XII., XIII., XIV., the measured depressions and tensions do not agree with those calculated, because the cable has evidently slipped.

$$\text{Length of rope} = 127 + \frac{8 \times 127^2}{3 \times 16{\cdot}7^2 \times 127}.$$
$$= 128{\cdot}2144.$$

The maximum droop of cable would occur when the curve ACB (see *Diagram* 2) became depressed at its centre until AD BD were straight lines.

Then,
$$ED = \sqrt{\frac{(128{\cdot}2144)^2}{2} - \left\{\frac{127}{2}\right\}^2}$$
$$= 8{\cdot}8.$$

Hence the maximum depression = CD,

$$,, \quad ,, \quad ,, \quad = 8{\cdot}8 - \frac{127}{16{\cdot}7},$$
$$,, \quad ,, \quad ,, \quad = 1{\cdot}195.$$

The depressions observed, viz. :—1·70, 1·80, 2·25, are, therefore, impossible if the rope remained fixed, and did not stretch.

F. R. de WOLSKI,

Lieutenant, R.E.

PAPER XVI.

ON THE NAVAL

ATTACK OF A FORTRESS.

By Commander C. Bridge, R.N.

A Lecture delivered at the R.E. Institute on 26th June, 1877.

It was not, I may assure you, without much diffidence and many misgivings as to my ability to treat the subject properly, that I accepted the proposal of your Secretary, and agreed to deliver here a lecture upon so important a question of war as "The Naval Attack of a Fortress." It is only respectful to the Members of this Institution, and becoming in me, to lay before you some of the thoughts which filled my mind when I was honoured by the invitation to appear here this evening in the capacity of a lecturer. The place which I have to-day undertaken to fill, but too unworthily, is that from which have spoken men of great ability and wide repute, not only to the officers of your own distinguished arm, serving, as your motto claims, throughout the world, but also to the students of the science of war of every service and of every country. To attempt to occupy the chair from which they have taught, with increased credit to themselves, and advantage to the many desiring to learn of them, is indeed, to essay the armour of Achilles, or perhaps even to imitate the impious audacity of Phaëtôn. But another, and perhaps even a greater difficulty has to be confronted by one, who like myself, comes forward to address you on a military subject which he has not, during any great length of time, made his especial study. He is somewhat in the position of an amateur addressing an audience of experts. To your branch of the profession of arms belongs much of the credit of having raised the conduct of war from a rude barbarian art to the elevation of a great science; of having directed some of the nobler of the moral and physical qualities of mankind, before wasted in senseless and unending conflicts, by methods matured after long thought and justified by a philosophical and scientific adaptation of means to ends desired. The difficulty of warlike operations has thus, through your instrumentality, been enormously increased, but the dignity of conducting them has thereby attained a commensurate augmentation. In the attack upon strong places this is especially the case; and the progress in fortification, and the increase in the power of defence in recent years, has fairly kept pace with the development of the methods of assailing them.

Within the last fifteen years we have seen the construction in our own country of vast works of defence, imposing in design, and so formidable in armament, that—when supplemented by the terrible secrets of torpedo-obstruction—they may well seem to give an impregnable security to the arsenals and dockyards which they have been erected to defend. An ancient article of the Military creed—that the ultimate advantage always rests with the attack—has thus received a severe shock. The labours which have rendered illustrious the names of more than one officer of the Royal Engineers have gone far to prove that the defensive capabilities of coast-forts are practically illimitable, whilst the offensive powers of ships and guns are finite, and perhaps their summit is now nearly reached. It is the business of officers of the service to which I belong to prevent the establishment of this proof. We are called upon to show cause why the Commander of a powerful fleet should not sit down with folded arms before a maritime fortress which the skill of Engineers has rendered formidable and difficult of attack.

You, Royal Engineers, who make it an occupation to work out the difficult problems of warfare, who see in the very difficulties of such problems fresh reasons for investigation and experiment, you would suppose that we naval officers are intent upon discovering some system of overpowering the strong-holds which every country with a sea-board has erected upon its shores, and of upholding the threatened superiority of the attack. Belonging to a fleet which has no equal upon the seas, it would appear to be one of our most pressing duties to devise means whereby we might prevent a rival, weaker on the ocean, from redressing the balance of inferiority by withdrawing his ships within the friendly shelter of his fortified harbours. The history of the naval operations in recent wars clearly indicates the great importance of so doing. Venice preserved by Austrian

Engineers in 1859; the numerous conflicts in the estuaries and rivers of North America during the Civil War; French iron-clad squadrons kept riding idly without the barriers of the North-German ports; not to speak of our own experience at Sebastopol and in the Baltic; all of these corroborate the view that to effectually crush an enemy's navy we must be able to capture or destroy the maritime fortresses within which his ships might take refuge. Yet towards this we have done little. Since our great victories in the early part of this century the study of naval tactics has been unaccountably neglected amongst us, and those who have of late essayed to revive it have either not thought it necessary, or have not yet felt able to go so far as to ascertain the system best adapted to a naval attack upon a fortress.

If there be one operation of war which more than another seems capable of being reduced to a fixed system, and being brought into obedience to definite and somewhat rigid rules, it is the attack upon a fortified place. The labours of a siege have been laid down in the text-books with nearly the accuracy of an almanac; and, given but the plan of the fortress to be attacked, the military engineer professes to teach the assailant not only the time required to make himself master of the place, but the occupation of his forces from day to day as well. This exactness we cannot hope to introduce into the system of attack to be undertaken by a fleet of ships. Steam has indeed in many ways rendered us almost independent of the winds and waves, but we are not yet in a position to disregard all meteorological considerations.

In discussing the manner in which a naval force can most profitably attack a maritime fortress we should recollect the remarkable situation in which the recent progress of the art of war, both by land and sea, has placed us. We find ourselves provided with new weapons, new armaments both of offence and defence, whilst at the same time we are almost without any practical experience of their use. So rapid has been this progress, that even the recent lessons of the war between the Northern and Southern States—almost the only ones in which we can hope to learn anything—are rapidly becoming obsolete. Changes in land warfare have been great since we last engaged in conflict with a European power; in maritime warfare there has been not so much a change as a revolution. Past experience and lessons of former times avail us little in forecasting the work that a future contest would demand of our seamen and our ships.

Yet, underlying this changed condition of things are intimations of great strategical laws which remain valid till now, and which will continue in force for all time. And beside this, the spirit of inquiry, which so distinguishes this age of ours, has attacked also the operations of war; and the result is a record of a long series of experiments which go far to enable us to estimate correctly the value of modern appliances for attack and for defence. In some cases these have been so complete as to be capable of being formulated; and we may now apply to the mechanics of warfare the rigorous methods of mathematical science. So that if we take up the ancient laws of strategy, embalmed for us in the story of many a deed of arms, and examine them in the light cast by the experimental knowledge of the last dozen years, we shall be able to arrive at some conclusions as to the conduct of a naval force operating against a fortified place. This, and this only, is what I can attempt to do here. To discourse fittingly of this important subject would require the limits of a treatise rather than that of an afternoon lecture.

Maritime fortresses may be roughly divided into two great classes: 1st, those which are complete in themselves and derive no benefit from the topographical and hydrographical conditions of their site; and 2nd, those of which the defences are strongly supported by positions for outlying works, and by the intricacy or shallowness of the channels of approach. Of these, Gibraltar may be taken as a capital instance of the first, and Portsmouth of the second. The latter, indeed, may be further sub-divided into fortresses on or near the coast, and those which line the banks of rivers or the shores of inland waters, such as the forts on the lower Mississippi, and at the entrance to Mobile Bay. Those of the last specified kind are—as a class—the least important of the three, and we are here enabled to appeal to experience as going far to prove that the passage of them can be forced by a strong and vigorous enemy. It is work something of this kind, which, at the beginning of a war, especially of a war with some partially Europeanised power, such as is often more or less imminent, that our navy would probably be called upon to do. But for the skill and patience with which the negotiations with China were conducted during the last complication, we might have found ourselves called upon only a few months ago to solve the question of passing a riverine fortress in the teeth of its garrison's efforts to stop us. If such an operation be decided on, it should be carried out as soon after the beginning of hostilities as possible. The very power of modern armaments interferes with the rapid adoption of the means of defence. In the report of the Chief of the United States' Engineers for last year appears the following remarkable passage :—

"In the event of war with a maritime nation the cruisers and war-vessels of the enemy could run into our harbours, and without landing could either destroy the property along our shores, or else lay the people under contribution. The accurate, detailed charts of our harbours and channels, published by the U. S. Coast Survey, are accessible to all such nations, and are doubtless in their possession. If the enemy possesses depôts and arsenals in close proximity to our stores, the arrival of such armed vessels will follow in a few hours after a declaration of war. Thirty-six hours' steaming could bring vessels from Halifax; six hours', vessels from Havana; and ninety-six hours', vessels from Vancouver's Island, to important harbours of the United States. There might be very little time for preparation to meet the assaults of iron-plated ships, for they are plated with 6 to 15 inches of iron, and carry rifled guns from 9 to 14in. bore, all of which guns are more powerful than any gun we have in our service. With a fleet, or even a single vessel of this kind in one of our harbours, it would be of no avail to collect troops in the city or town threatened.

"Suppose we could concentrate 100,000 men in twenty-four hours at the point threatened, of what use would they be against the armoured ships?

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"The parapets and traverses of earth and sand must be three, and even four, times as thick and massive, as they were built to resist the armaments of 15 years ago. Where the parapets of earth were ten feet in thickness, now they must be forty feet. Guns that were formerly dragged with ease by fifteen or twenty men, and placed in position over night, are now supplanted by armaments of such huge masses that special mechanical appliances are required to move them even slowly, and they cannot be lifted from their supports without the aid of hydraulic power. No matter how many men may be at our disposal the time required to place the modern armaments in position is vastly greater than for the guns of fifteen years ago; and before such works could be improvised the enemy in his ironclads will have accomplished all he desired, and have sailed or steamed for some other harbour to repeat the injuries of the first."*

This, coming from such a source, is fair proof of that of which we have had, in the history of the last quarter of a century, many other proofs, viz. :—the importance of making attacks as early in a war as practicable. This attack, called by the French *entrée de vive force*,† is the simplest of all those which a naval force would be called upon to make upon fortifications of any importance. We may examine the rules which the leader of such a force would have to observe in carrying out an operation of the kind.

* Report of Chief of Engineers in 1876. Washington, 1876. Part I., p. 4.

† *De la Guerre Maritime*, par. R. Grivel. Paris, 1869, p. 30.

First: as has been shown, it is highly desirable that the attack should be made soon after a declaration of war. Maritime fortresses are supposed to be always in a condition to withstand an attack. The Russian Government a few months ago, in a published scheme for the armament, under the new conditions of warfare, of the strong places of the Empire, laid it down as a rule that every fortress on the coast should have everything constantly in readiness to resist a hostile force. The fall of Soukhoum Kalé, unimportant or important as it may be as a defensive post, may show that this desirable readiness is not always attained in time. Therefore, an enterprising enemy has the chance of unpreparedness on the part of the defence on his side if he lose no time. Porter reported* that a heavy gun, which had been counted on much by the defenders of the Confederate forts on the Mississippi, had been removed for some improvement to be made in it, and had not been brought back in time to be used against the Federal fleet.

Second: the chief of the attacking force should make himself intimately acquainted with the nature of the place. "An *entrée de vive force*," says Capt. Grivel,† "cannot be attempted unless a laborious study of the charts, the works on shore, the movable defences, and the natural or artificial submarine obstacles justify the calculation of chances." The *Bulldog*, a vessel belonging to Her Majesty, was lost some years ago in the West Indies in consequence of grounding upon a shoal during an attack upon the batteries of some Haytian insurgents. The existence of this shoal could not have been distinctly known. In the preliminary operations which were followed by the Battle of Lissa, in 1876, Admiral Vacca's division of Persano's fleet steamed into the harbour of San Georgio, but was unable to efficiently support his friends on account of the difficulty of manœuvring from want of space inside the harbour.‡

Third: the amount of movable force—vessels, gunboats, torpedo-boats, &c.—at the disposal of the enemy should be known. To run successfully past forts and emerge from their fire in the shattered condition probable after such an engagement, to fall in with a fresh naval force beyond the batteries, would be to court failure, even though the hostile squadron might be inferior to the whole force of the assailant. After Farragut had passed the forts at the entrance to Mobile Bay his fleet encountered Buchanan's small squadron, and

* Von Sheliha, *Coast Defence*, p. 22. See Porter's report to Admiral Farragut of proceedings of "bomb fleet."

† Grivel, p. 30.

‡ Hozier, *The Seven Weeks War*, vol. ii, p. 309,

but for the lucky shot which rendered the Confederate ironclad unmanageable, his losses would very likely have been far more serious than they were.

Fourth: if obstructions exist they should either be removed, or means sufficient to break through them be rapidly prepared. "No fleet can force a passage if kept under the fire of heavy batteries by properly constructed obstructions."* In the second attack on the Taku Forts in 1859, the "boom" placed by the Chinese across the channel kept some of our gunboats immediately in the line of fire of the guns. Sir James (then Captain) Hope cutting the chain at Obligado, in South America, in 1845, enabled the Anglo-French forces to get past the batteries on the river's bank.†

Fifth: the submarine defences, torpedoes, &c., should be first removed or destroyed, or the free passage through them be ascertained.‡ The loss of the Federal Monitor, Tecumseh, at Mobile, was, as I was informed by officers present in the engagement, in consequence of her being taken over a line of submarine mines, of the position of which Farragut was aware, and of which he had warned his captains.

Sixth: the enemy's works should, when possible, be exposed to a preliminary bombardment. Forts Jackson and St. Philip, on the Lower Mississippi, were compelled to submit to the fire of twenty mortar-vessels, commanded by Captain Porter, for a period of six days, before Admiral Farragut forced the passage. The effect of this bombardment may be estimated from Porter's statement that 1,500 shells were fired in twenty-four hours.§ Of these he claims that only 1 in 20 failed to explode.|| And the enemy, he says, gave "the credit of reducing the fort to the bomb-fleet."¶ These mortar-vessels were stationed at distances varying from 2,850 yards to 3,680 yards, and in some cases were secured against return fire by being placed behind a point of land, and were further concealed from the view of the besieged by the intervention of "a thick wood, closely interwoven with pines," and their mast-heads being dressed with boughs to complete the concealment.

Seventh: arrangements should be made for towing off, or at least removing out of their consorts' way, such vessels as may be disabled by the enemy's fire or submarine defences. In a narrow passage a ship some distance from the sternmost vessels of the attacking column might, if sunk or rendered unmanageable, throw all the

* Von Scheliha, p. 124. † Yonge, *History of the Navy*, vol. ii, p. 561. ‡ Grivel, p. 30.
§ Von Scheliha, p. 59, || Do. p. 93. ¶ Do. p. 22.

ships astern of her out of action, and split the force to which she belonged in two. As a general rule—if the protecting batteries are at all formidable—to run past them should not be attempted unless the channel be of sufficient width to allow of the following ships to clear themselves of such accidental obstacles. At Mobile Farragut's own column was able to pass clear of the sunken Tecumseh.

Eighth: a division of the force should be told off previous to the engagement to set about completing the work which was the real object of the passage as soon as the attacking vessels had got beyond the batteries. The remainder should prevent the enemy from repairing his defences, or obstructing the channel afresh, and thus cutting off the retreat of the successful assailants.

With respect to fortresses of the class of which Gibraltar has been named as the representative instance, it does not seem clear—even if they be far inferior in strength to that celebrated stronghold—what good purpose would be gained by a purely naval attack on them. They do not, as a rule, protect arsenals of importance, nor are they the most suitable refuges for ships that do not dare to keep the sea.

Since the completion of the modern works Cherbourg owes a not unimportant portion of its powers of defence to the outlying forts and batteries on the rock and mole, and, therefore, hardly belongs to the class in question. When taking part in a combined naval and military campaign, a fleet may be called upon to assist in the reduction of such a place. Aided by a besieging army on shore the work of the navy would be far simpler in such an attack than perhaps in any other. Hydrographical conditions would be such that no precautions, or but few, need be taken against submarine defences and obstructions. The true work of the naval force would be quite supplementary to that of the land force.

Batteries, comparatively secure against the besiegers' guns on shore, might be enfiladed by the fire of ships, which in general would be free to choose their own positions. Particular works possessing a power of annoying the besieging force might be left to the fleet to be silenced or destroyed. It is not likely that a garrison, unless very weak in numbers, would submit to a vigorous cannonade from ships without making some reply, so that in this way its attention might be distracted. The moral effect upon a body of defenders cooped up in the circumscribed limits of such a place consequent on finding themselves between two fires is likely to be considerable. The contest between the fortifications and the ships would, in such case, resolve itself into an exchange of artillery fire. The ships would have all the advantages due to their mobility. They might be so placed as to offer no considerable mark to the hostile gunners, and at the same time to concentrate their fire on points determined on. It is not likely that in such an attack an Admiral would permit his ships to remain stationary, as was done at Sebastopol in 1854,* but, "keeping always in movement they should deliver their fire in succession."

The supreme naval effort might be deferred till the period of having recourse to the services of the assaulting columns was at hand. In the final bombardment of Fort Fisher Admiral Porter's fleet had fired, on three days, over 50,000 shells against the fort.† The work was captured by the assaulting parties of the land force after its parapets had been in effect destroyed by this furious fire. The attention of the garrison was directed to a body of seamen and marines which Porter was preparing to land from his ships. A less strenuous resistance was in consequence offered to the federal columns of assault which penetrated its works, and finally became masters of the place.

A naval attack upon a first-class maritime fortress, owing much of its strength to the hydrographical conditions of its site, is one of the most important operations of naval warfare. The prognostication of Sir Howard Douglas concerning the Crimean war probably indicates, with considerable accuracy, the course that a contest between naval powers will take in future.‡ He says "in the remarkable naval war in which we are now engaged there will, to all appearance, be no fights on the open sea, ship against ship, fleet against fleet, as of old; but attacks of fleets against fortresses and other land defences." The blockade and attack of the fortified places on the coast, and the sending out of cruisers to prey on an enemy's commerce, seem to be the duties in which in wars to come the navy will be most engaged. The mastery of the sea, or at least an unquestioned superiority of strength upon it, will be an inevitable condition of success for that fleet which essays to attack a great maritime fortress. The progress of science has rendered such attacks more and more difficult, and they will hereafter approach more nearly than heretofore to the operations of a great siege on land. Something more than merely to stand in and cannonade the opposing batteries for a certain number of hours—a proceeding with which the history of so

* Kinglake, vol. iii., p. 387.

† Von Scheliha, p. 43.

‡ *Naval Gunnery*, p. 343.

many navies has made us acquainted—will be required now to reduce the stupendous works of recent construction.

First: it will be requisite that the navy which proposes to undertake such an attack shall have the command of the sea. Now that the use of steam power is universal, the mere fact of an enemy's fleet having been withdrawn to a distance from the place which it is intended to attack will not justify an Admiral in venturing to engage in so great an operation. To be caught by a hostile squadron entangled in the proceedings of a siege, with his ships more or less suffering from the resistance of the defenders, would lead more likely to destruction than defeat.

Second: the bearing of the attack on the general aim of the campaign or war should be distinctly understood. To risk ships and lives in attempting to reduce fortifications, the capture or destruction of which would tend little to influence the result of the war, should be carefully avoided. Against any such error of his own a commander is likely to be protected by the government of the country to which he belongs. Ministers, in possession of information from all quarters, and receiving reports from the leaders of both the land and sea forces wherever employed, are sure to lay down for the officers commanding the general plan of campaign which they should adopt.

Third: the season should be carefully selected. The dangers of delaying what would probably prove a protracted work, in the Baltic, for instance, hardly requires to be noted. But in all coasts certain seasons are less favourable to a prolonged stay than others. In the East, for example, the geographical position of many places renders them practically inaccessible during one monsoon, or half the year. Other places enjoy not only serene weather, but also a temperate climate for several months, whilst during the remainder of the year the seasons are both tempestuous and pestilential. On some great rivers the protecting fortresses can only be approached for a limited season. The depth of water, in general too shallow for powerfully armed ships, only increases sufficiently to give hopes of making a successful attack at the period of the melting of the snows near the upper waters.

Fourth: no attack upon a fortress of the first class must be undertaken until a sufficient force and a proper supply of stores have been collected. A mere fleet of heavy ironclads will not suffice to reduce an important place. The command must contain vessels of several descriptions; light draught gun-boats, torpedo boats to resist the sorties of the garrison's floating defences, mortar-boats to bombard distant works. The quantity of stores requisite to a great undertaking of the kind will be prodigious. There must be provided full supplies of ammunition of all sorts, of counter-mines, of protective obstructions, and also of the articles required to make good defects in the ships themselves, and in their armament and machinery. The coast fortresses which the Federals attacked so frequently during the civil war were not by any means first-class fortresses, according to European ideas; yet, for their reduction, it was necessary to maintain a stupendous fire. In the second siege of Sumter "the batteries expended 5,009 shells." One captain (Stevens) reported "that 455 shells were fired in seven days." From the shore and the ships "2,864 shot and shell had been fired against battery 'Wagner' during forty-two hours." At Fort Fisher "during the last bombardment, on January the 13th, 14th, and 15th, there were fired over 50,000 shells against the fort."* If, remembering these figures, we reflect that the supply of ammunition to Her Majesty's ships is but 85 projectiles per gun on the broadside, and in no case more than 170 per gun, we shall see that the amount of reserve stores, required in such an undertaking as that we are considering, would be vast.

Fifth: some conveniently placed and easily defended harbour in the neighbourhood of the fortress to be attacked must be seized by the attacking fleet before beginning. It is obvious that the fleet itself would be numerous. At Sweaborg, in 1855, the allies had six line-of-battle ships, besides frigates and steamers, twenty-one English and French mortar-boats, and twenty gun-boats.† At the passage of Forts Jackson and St. Phillip, Farragut had thirty steamers, besides twenty-one mortar-boats.‡ In December, 1864, Rear Admiral Porter opened on Fort Fisher with the batteries of not less than thirty-three vessels, besides eighteen in reserve.§ In the following January, he re-opened fire from forty-four ships. The supply fleet would also be very large, and it would be found essential that some secure anchorage should be at hand for many vessels, both to ensure their safety, and to prevent the movements of the besieging squadrons being hampered.

Sixth: the attack should have always some definite object, and this object should not be lost sight of. For instance, in the case of such a fortress as Cronstadt, as it appears from the latest map in

* Von Scheliha, pp. 9, 16, 33, 36.

† Yonge, vol. ii. p. 660. ‡ Fletcher, vol. i. p. 402. § Von Scheliha, pp. 33, 35.

my possession,* an assailant might propose to himself to reduce the various forts until he could reach a position from which to destroy, by shell-fire at high angles, the arsenal buildings and the ships in the port. With this object in view, the attack would naturally be made from the north of the island. Indeed this, as we have been told by Sir Howard Douglas, would be a law governing such operations. Outlying works should be first reduced, and the operations should proceed so as to compass the destruction, or silencing of the various forts and batteries which support each other by their position and the direction of their fire. "Isolated points of defence mutually protecting each should be attacked in detail, and successively reduced, after which the fleet may arrive at and attack the main position."†

Seventh: the fleet should be split up into divisions, to each of which some particular duty would be assigned. A flotilla of mortar-boats would be told off to bombard those defences which could be best reached by, and would be likely to suffer most from, curved fire. Barbette batteries and hastily constructed earthworks would be especially liable to damage from such attack. Divisions of light-draught gun-boats armed with heavy guns should be distributed about, so as to converge their fire upon particular points. The large ironclads should be placed where the water would be deep enough to float them without risk, where there would be room for collections of them to manœuvre, and where they could bring a heavy direct fire upon defences impervious to other attack.

Eighth: means of protecting the attacking squadrons should be devised. Floating obstructions formed of boats and chains might be arranged as a screen against torpedo-boats, behind which screen ships might move and deliver their fire without much danger of counter-attack. The swift torpedo-boats of the assailants should be kept in readiness on the flanks, as it were, of the bombarding ships, to repel any such counter-attacks made by the besieged.

Ninth: a carefully devised plan of clearing obstructions should be prepared. As Captain Grivel‡ observes, "If the natural difficulties vary according to the configuration of the place, we must not forget how far the genius of the defence can complicate the task of the assailant." The dangers of the submarine mines have, in some

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* Courteously supplied me with other valuable information by Mr. Wild of Charing Cross.

† *Naval Gunnery*, p. 351.

‡ *De la Guerre Maritime*, p. 31.

respect, been neutralized by the power of the marine counter-mine, and an extensive supply of these objects should be at hand.

Tenth: careful and accurate surveys should be made of the place, of the surrounding waters, and of the works. However perfect and minutely detailed may be the plans and charts which the attacking commander may be placed in possession of, he should not rest satisfied with them unless they be of very recent date, or executed by officers under his command. In many of our own wars, whatever success has attended the naval operations has in great part been owing to the intrepidity and skill of our surveying officers; to prove this I need only recall the names of Collinson in China, Spratt in the Black Sea, and Sulivan in the Baltic.

It is now proper to consider the relative chances of success of the attack and of the defence, due regard being had to the conditions of modern warfare. It must be admitted that the balance of authority is decidedly against the feasibility of successful attack on a fortress of any strength by a fleet of ships. It is true that some men of unexampled experience of that style of warfare have raised their voice on the other side; but they are a minority, an important and influential minority it is true, but still only a minority after all. Sir Howard Douglas, whose name British Naval Officers should always regard with gratitude and veneration, has said that "the attack of fortresses and powerful land batteries with a naval force only, must ever be a hazardous and desperate undertaking."* It should be remembered that the distinguished author wrote this at a time when considerable attention had been paid to the work of strengthening coast defences, and before the occurrence of the great revolution in naval architecture and the armament of ships of war, which we have seen within the last fourteen or fifteen years. Rear Admiral Porter, of the United States' Navy, than whom no man had more experience of engagements between ships and land fortifications, held a very different opinion, and thought—or indeed was convinced—that provided the channels were clear of obstruction, a naval force, not greatly superior in gun power, had more than a fair chance of succeeding in conflicts of the sort. But with respect to his views also, it is only just to recall that he wrote fresh from the experience of several combats between ships, armed and protected on the very newest principles of the time, and forts constructed or planned thirty or forty years before, and intended to

* *Naval Gunnery*, p. 347.

withstand the attacks of vessels which, when the Admiral himself came to command fleets, had become quite antiquated and obsolete. Many of the most powerful coast fortresses, even of the present day, still have much of their works built of masonry; and Colonel Collinson, R.E., has said "no masonry, except of very massive character, can be expected to stand for many hours the effect of such projectiles as those of the 300-pr. or even the 150-pr. Armstrong gun."* Now unless the coast batteries and forts of the world have undergone an almost complete re-construction since the introduction of the newer heavy naval guns, we may apply to them, in view of the greatly increased power of artillery, the same argument *à fortiori.*

Sir Howard Douglas has also said that "however successful a naval attack of a fortress or arsenal may be, the work of destruction can never be effectually accomplished by ships. The sea defences may be silenced, guns dismounted, parapets ruined, magazines blown up by mortar shells, and habitations devastated by the cruel process of bombardment; but no substantial demolition of the defences, or material destruction of the public works and property can be effected unless the damages inflicted by the attacks of ships be followed up and completed by having actual possession of the captured place for a sufficient time to ruin it entirely. No naval operation, however skilfully planned and gallantly executed, can alone reap the fruits of its victory."† Col. Soady, R.A., in his work on the *Lessons of War*,‡ quotes a somewhat similar opinion of Sir William Jervois; and, in another passage§ to the same effect, says: "A fort is able to inflict far greater damage upon its assailant than the latter can inflict upon it; whilst it will hit the assailant nearly every time, the chance of the assailant hitting it more than once in the same spot are small. Further, one shot may send a ship to the bottom, whilst the fire from a ship during action is more or less inaccurate." Now it is hardly too much to say that these statements have been directly traversed by the actual experience of the war in America. Von Scheliha, writing in the full light of that experience, has it that "the sinking of a vessel by artillery fire is usually the result of a fortunate chance which has directed the shot to some vital spot." As a matter of fact powerful forts were completely silenced by the fire of guns; and though not indeed taken by assault, were so far made useless to the defence that any ship might have passed by them with impunity. After the second bombardment of Fort Sumter only a

* *Professional Papers*, R.E., vol. xiv., p. 69, 1865.

† *Naval Gunnery*, p. 353. ‡ *Lessons of War*, p. 163. § *Ibid*, p. 157.

few serviceable field guns remained, and even these had to be placed under shelter by day.

Again we have Sir Howard Douglas' own authority for believing that the configuration of many points of a coast which have to be fortified, and the low elevation of such points, conduce to the success of a naval attack. "Batteries placed nearly on a level with the water are far more subject to the fire of ships, and are much less formidable to them than batteries elevated somewhat above the surface of the sea. * * * Should any guns be mounted *en barbette** they would inevitably be dismounted." So too, "An enemy will always have the advantage of being able to concentrate against any number of guns ashore a larger number of guns on his ships; may commence an engagement or break it off at his own convenience; may choose his own ranges and positions; * * * the fire of 100 guns or more may be concentrated at the same time."† Thus the naval force has on its side the advantage of the artillery law deduced from the experience of the latest wars, viz.:—The most effective use of artillery power lies in the distribution of the guns and the concentration of their fire.

It is true that a naval force acting alone can hardly hope to take possession of works which it has battered to silence by the superiority of its fire. Nor in a siege on land does it lie with the engineers who trace the batteries, or the gunners who work the guns, to seize the place when its fortifications have been breached. That is the duty of the columns of assault, of the "forlorn hope," drawn from the ranks of the infantry corps of the besieging army. But what a naval force may hope to do, and what it has done ere now, is to reduce the batteries to such impuissance that it can disregard them, and then stand in and destroy the ships or works which the same batteries were erected to protect.

In considering what lies before a fleet of ships to which it has been entrusted to reduce a great fortress, the first thing that occurs to us is how to remove the obstructions which the defenders are sure to have constructed. The ruinous result of using such permanent obstructions as sunken ships are now so well known (for they injure a harbour far more lastingly than anything an enemy is likely to do) that we may believe they will be rarely made use of in future. The processes of nature will not unfrequently come to the assailant's aid in this particular, and it has been noted that sudden floods and violent storms have shattered defensive obstructions, and even displaced

* *Naval Gunnery*, pp. 335-6. † *Von Scheliha*, pp. 43-4-5.

and neutralized the effect of submarine torpedoes. Floating obstructions must be very strong to withstand the shock of a steam ram of not very large size, and—providing the general depth of water be sufficient—such a vessel may probably be advantageously driven against it. Should the obstruction be placed so as to be under the heavy fire of the guns of the defence—to which it would not be advisable to expose a ship till the obstacle was removed—the batteries must first be subjected to a heavy bombardment from as near as the obstructions will permit; or explosives, intended to burst on contact, must be sent in with the tide, or be deposited against it by electrically-steered steam-boats.

Submarine mines undoubtedly present a formidable obstacle to the attack. Still, there is good reason to believe—from our recent experiments—that they too can be removed or destroyed. I may quote from a very interesting account of some experiments which were carried out at Portsmouth only a short time ago. They were "intended to illustrate the method of entering an enemy's harbour where torpedoes are known to be deposited. This can now be as certainly effected by what are known as countermines as, in the case of land warfare, a fortress can be gradually approached by sappings and trenches. These countermines are conducted in various ways, but they have all the same purpose in view, which is to destroy the enemy's mines by exploding others in their midst. It is believed that the explosion of 500 lbs. of guncotton below water will clear an area having a radius of 120 yards. The method generally adopted is to take advantage of the tide, the current, or the wind, and to drift the countermine into the required position. When the charge is too heavy to float in consequence of its own buoyancy, the necessary floatation is secured by attaching it to some foreign object in the shape of a cask or buoy. * * * * A net containing 15 lbs. of wet guncotton was discharged; and, in order to show that there need be no limit to the number of countermines in the same connexion, twelve small charges of guncotton, representing as many countermines of 500 lbs. each, were simultaneously discharged, thus demonstrating the possibility of extending these operations over wide areas of disturbance." *

Sweeping, "creeping," dredging, diving to cut electric wires are all methods which have been tried with success. With regard to the distance from the defenders' works at which these mines are likely to be encountered, as yet no very safe guide can be laid down. Some officers are of opinion that it will not be advisable to lay down such defences much beyond the effective fire of the guns and projectiles that would probably be used against exposed boats. My own belief is that we should be ready to meet with them very much farther out. But this is a question more for the engineers of the defence than for

* *Times*, June 6th, 1877.

those of the attack. In any case an assailant will have to proceed with caution, and to clear carefully every step of the way, even though he begin his operations at a very great distance from the works.

The attacking fleet must be in a condition to resist the offensive sorties of the garrison. These will either take the form of squadrons issuing from behind the fortifications to enter into a regular engagement, or isolated attacks of torpedo-boats, or of Whitehead torpedoes. Unless the attack be strong enough to keep a division of ships constantly in readiness to engage such squadron as the enemy may have to send out, without interrupting the fire upon the batteries, it would be better not to undertake to reduce the place at all. The heavy ships and gunboats charged to maintain a fire upon the fortress may be protected by obstructions—easily removed when an advance is requisite—which will effectually prevent the approach of any torpedo-boat yet known. If the firing divisions are manœuvring at certain distances from the forts, they may move to and fro or round and round, as may be desired, behind a screen of boats and chains which it will be almost impossible to break through, and may be further protected by a few swift steamboats, which can run down or engage the craft sent out by the defenders.

Torpedo attacks are likely to be made under cover of the darkness. The screen of chains and boats, and the swift steamers just spoken of can be supplemented by the various methods of lighting up approaches which have recently been brought into notice. I will quote again from a late account of some of these methods.

"When it is established that no gun-torpedo can be effectively launched to insure impact within moderate short range, and that no torpedo launch can act with effect except it absolutely approaches the vessel within striking distance, neither can any torpedo be affixed or placed near a ship except the forlorn hope actually approach the vessel; the most valuable means of defence, and the one to which special attention should be directed is that of illumination. Light of sufficient power to disclose any object attempting to enter a cordon of illumination round a ship, the ship itself remaining in darkness, is at once the simplest and most effective precaution that can be devised against night attack. * * * * * * Within the last few weeks a very important advance has been made towards solving this problem of illumination at sea by an adaptation of what is known as Holmes' distress signal, in the form of a shot for illuminating purposes, to be fired from mortars at ranges varying from 500 to 2,500 yards. These signals possess the remarkable property of emitting a very powerful white light the moment they come in contact with the water, and when once ignited are absolutely inextinguishable by either wind or water, and burn with a persistency that is almost incredible, 30 or 40 minutes being an average duration. * * * * * Some half dozen of these shots, fired from an ironclad or gunboat, would effectually surround her with an impassable cordon of light, while the vessel herself would remain in darkness."*

In addition to this illuminating shell another has been invented by a M. Silas, of Vienna, out of which, when fired, two streams of illuminating matter are poured upon the sea. There can be no doubt that—when the alarm has been given by the look-out boats stationed in advance—to be able to illuminate the path of the enemy's approach will add greatly to the facility with which ships lying off an enemy's fortress can be protected against night torpedo attack.

The main attack upon the batteries will, of course, be by artillery fire. The use of mortars will probably be largely had recourse to. Recent experiments with curved and high-angle fire in Russia have shown how formidable such fire is to ships, no matter how thick be the armour on their sides, and also to fortresses. At Nicolaiev towards the end of last year, after two days' practice with mortars at targets representing circular ships, or *Popoffkas*, and large iron-clads, it was found that on one day 33 per cent. of the shells fired, and on the other day 22 per cent., fell on the space representing the deck.† At Cronstadt 22·2 per cent. of the shells fired from twelve 6-inch mortars at a moving object, a barge smaller than an ordinary gun-vessel, struck the target.‡ This will show some of the dangers from vertical fire which ships attacking must expect to incur. As Colonel Inglis, R.E., has said, "The general conclusion to be drawn is that a deck plated with two thicknesses of $\frac{3}{4}$-inch iron is not proof against short-range 9-inch shell."§ The land defences, at the same time, are extremely open to the dangers of such vertical or mortar fire. We have seen what Porter's "bomb fleet," did on the Mississippi. To quote a former authority, "A bomb ship may, without much exposure, do great damage to an extensive fortress or arsenal; which, being a large object, ought to be struck at every discharge at upwards of 4000 yards, whilst the bomb ship is a mere speck on the sea at that distance."||

With respect to the method of delivering the direct fire against the defences of the place, it may be laid down that, unless the mortar vessels and vessels firing at high angles can be protected by some intervening point of land of sufficient elevation, all engaged should do so whilst in motion. This has been known as an unquestioned advantage of the use of steam locomotive power; and at Sweaborg

* *Times*, June 5th, 1877. † *United Service Magazine*, Dec. 1876, pp. 475-6.

‡ *Revue d'Artillerie*, vol. ix., p. 489.

§ *Professional Papers*, R.E., vol. xx., p. 47. || *Naval Gunnery*, p. 355.

and Odessa ships moved in circles whilst engaging the batteries, and would have done so, but for the change in the plan at the last moment, at Sebastopol. The circle does not seem so well adapted to ensure the protection of the vessel and the rapidity of fire as the ellipse. If the circle be of sufficiently large diameter to withdraw the ships, on their outside passage, out of range of the guns of the defence, the traversing of its circumference will be necessarily slow. If the diameter be reduced the exposure will be considerably increased. In attacking such a fort as that marked Alexander on Mr. Wyld's map of Cronstadt, the position selected would naturally be that on the capital of the Northern bastion. An ellipse described at a distance of 3,500 or 4,000 yards from the bastion might have a major axis of considerable dimensions at right angles to the capital; and the curve presented to the fort would be flat enough to allow of more than one discharge of the guns in passing. On getting nearer to the defences the major axis of the ellipse should be in the other direction, that is in the line of the capital, so that the ships on delivering their fire might go to a considerable distance outside the fighting range. Both figures would be contained very nearly, if not quite, within the limits of the "sector of impunity," or horizontal *dead angle.* The speed at which these curves should be described by the ships would not fall short of six knots. Several tables of the probable number of times a moving ship could be hit by the guns of a battery have been constructed, *e.g.* by Captain Grivel in his *Guerre Maritime*; * but it will suffice here if I mention that it has been found by experiment in this country that, "Crossing the range of a 12-ton gun mounted in a casemate where the traversing angle is 70,° at a distance of 1000 yards, a vessel moving at a speed of 10 miles an hour may be fired at six times. The 22-ton gun would have fired at her three times."† Occasions may occur when it is possible to select a position from which a ship can fire against a battery without having to move about. I can remember one such case in my own experience during the Russian war, when a ship, which her captain had run in as close as the depth of water would permit, was able to take up a position so far to the left of the embrasures of an earthwork specially constructed as a defence against ships, that the guns could hardly be trained to reach her. The great advantage on the side of the ships will be their power of distribution and of concentrating their fire, in addition to the small objects presented by many gun-boats, which will carry the heaviest, or almost the heaviest guns.

* p. 37. † *Report of Committee on Fortifications*, app. 2, p. 6.

Looking back and reviewing the whole question, it is not easy to avoid the conviction that to attack a great fortress we should require a vast force. Heavy ironclads would have to be numbered by dozens, and gun-boats and mortar-boats by fifties. We attempted little, or failed in what we did attempt, in the war with Russia, because, as we can now—by the light of present experience—see, our means were ridiculously inadequate to the end we proposed to ourselves. It will be the same again if we do not recognise the fact that our preparations should be such as to give us some promise of successful performance.

In conclusion I may say that I am very apprehensive of having said to you little that was worth hearing. I have possibly recalled some facts that had once been known, but have been now forgotten. I must plead in extenuation of any failure to interest or enlighten, what I said in my prefatory remarks; and I may add that this paper has been composed under somewhat serious difficulties. I returned to England only a few weeks since with health shattered by a rather long service abroad; and since I have been at home, since indeed I began the composition of this paper, I have had an attack of illness which rendered any work all but impossible. Added to all which there have been the distracting influences which act upon one who has recently returned to the society of friends whom he has long been absent from. I cannot regret, however, that I accepted the invitation extended to me on behalf of your Institution. It has turned my attention to a branch of warfare too much neglected of late; and it has enabled me to realise, in some measure, the immense debt of gratitude which England owes for her security to the officers of her Royal Engineers.

CYPRIAN BRIDGE,

COMMANDER, R.N.

PAPER XVII.

ON THE UTILIZATION

OF

CARRIER PIGEONS

FOR MILITARY PURPOSES.

BY W. B. TEGETMEIER, ESQ., F.Z.S.

A Lecture delivered at the Royal Engineer Institute, Chatham.

IT may appear bold on my part, as a civilian, to address an audience chiefly composed of military men, on a subject that apparently has but a slight bearing on military science, but I am emboldened by the recollection of a great authority, one who was well versed in a variety of subjects, who stated that he owed the vast fund of information he possessed to a habit of never neglecting an opportunity of acquiring knowledge from any individual, however humble. He saw that every man possessed in his own speciality something from which he could learn; and, possibly, I may have, from the special knowledge which I possess on this subject, something to say that may be interesting to you, and that may be found to be not without its interest and value, looked at from a purely military point of view.

The application of the homing pigeon to military purposes is one that I think I had perhaps better introduce by a few remarks on the history of the bird, and on the origin of the faculty which it possesses.

The wild original of our domesticated pigeon is the blue rock dove, the *Columba livia* of naturalists; in its wild state it inhabits rocky places on the sea shore, and seeks its food from a wide expanse of country, sometimes at a distance of many miles. In order to return to its nest and rear its young, which are fed by the parents during a period of some weeks, the birds must possess the habit or faculty of observation, and be able to retrace their flight under all conditions of atmospheric variation.

This pigeon is one of the few birds that possess the instinct of domesticity. Many persons imagine that almost all animals can be domesticated. This is an idea that is repudiated by naturalists, who know that only about 40 of the whole of the animal creation, consisting of several hundred thousand species, have been reduced to a domestic state by man; it is doubtful, indeed, whether there are many more that could be domesticated. For example, it is impossible to domesticate pheasants. They may be reared, generation after generation, in aviaries, but as soon as they acquire the power of flight they go off to the woods, and are no longer domesticated animals. On the other hand, the blue rock pigeon taken from the nest and placed in a dove cot at once becomes attached to the spot, and remains a domesticated animal—not necessarily a tame one, because it may be as wild as possible, and yet, at the same time, domesticated, or attached to its own domain or home. The possession then of this faculty of domesticity, and also that of returning to its home, unite to give the peculiar value of this pigeon as a homing bird.

Like all domesticated animals pigeons are subject to great variation; in some of the varieties this faculty has been cultivated to a very high degree, in others it has not. In England we apply the term carrier pigeon to a pigeon that will not carry at all. What is commonly called a carrier is a fancy pigeon, which is valued not on account of its power of flight, which it possesses in a very limited degree, but for the enormous amount of corrugated flesh that exists about its beak and its eye. The birds that are really trained for flying are birds that have no fancy characteristics. They are valued solely on account of their great power of flight, a power that is indicated by the enormous breadth of wing feathers, the extent to which they overlap, and for their powerful wings, with vast muscles to move them; all such characteristics as colour are put on one side, and the young birds are reared from those who have performed the longest distances in the least possible space of time.

To show you how strong this faculty of homing is in a good bird I may mention that one not only flew to Brussels in a race, starting with 440 competitors, but having been returned to London for exhibition, and being let accidentally out, she went back to Brussels a second time, unaccompanied by any other pigeon.

The Belgians have cultivated this breed of homing pigeons to a much greater extent than any other people. In Belgium pigeon racing is really the national pastime. Thousands of pounds are devoted every year for the training and racing of pigeons. His Majesty the King of the Belgians gives the chief prize, and the Heir to the throne gives the second prize in the great national race of the year, which is usually from some town in the south of France. There are hundreds of societies, and tens of thousands of amateurs, interested in pigeon racing, all of them keeping this variety of pigeon, and racing it various distances, from fifty to four or five hundred miles. Sometimes they race from as far as St. Sebastian, but usually their long races take place from some town in the south-west of France.

Having called your attention to what is being done in Belgium, I would mention a few of the uses that have been made of these *voyageur* pigeons in England.

Before the introduction of the electric telegraph pigeons were very largely used by the stock brokers. The news of the battle of Waterloo is said to have been transmitted by pigeon express, and received by the Rothschilds before it reached the ears of the British Government. Pigeons have also been largely used for sporting purposes, conveying messages from the different race courses to London, announcing the names of the winning horses. Not only in England were they used in this way, but likewise abroad. One example I may mention, because it bears somewhat upon our subject. The editor of the *Colombo Observer*, in Ceylon, had a number of homing pigeons which used to bring intelligence from Point de Galle to the capital, Colombo, a distance of from 70 to 80 miles. Ships going out to India and China touch at Point de Galle, and then go on their course, and before the establishment of the electric telegraph the information that the ships brought was conveyed from Galle to Colombo by pigeons. When the news of the fall of Sebastopol arrived, the Governor caused a salute to be fired in honour of the victory on the faith of intelligence brought from the Point de Galle by pigeons. On the establishment of the electric telegraph, Dr. Ferguson, the editor, gave up his birds. But he afterwards found that the delay in the transmission of messages by the electric telegraph, combined with the not infrequent inaccuracy of such messages, were so serious that he applied to me for a dozen pigeons in order that he might re-organize his pigeon telegraph, as being much quicker and more reliable than the electric telegraph as worked by the natives.

In one of the races which took place from the Crystal Palace to Brussels it was agreed that on the liberation of the birds, at twelve o'clock in the day, I was immediately to despatch a telegram to the secretary of the society in Brussels. I accordingly did so, announcing the flight of the pigeons, the nature of the weather, and the direction of the wind, which would influence the rate of flight. The first pigeon arrived at Brussels at 20 minutes past five, the weather not having been very favourable. The telegram announcing the departure of the birds arrived there at half-past five, so that the winning pigeon on that occasion beat the telegraphic service by ten minutes. I give this as an interesting example of the speed at which they fly; of course I do not say that the electic telegraph will not equal the pigeon-despatch provided special arrangements are made, but, practically, in a great many instances the pigeons will beat the telegraph, and they did so on this occasion.

With respect to the speed at which pigeons fly, I may mention to you that for short distances, with good weather and a favourable wind, it will approach 60 miles an hour. Pigeons have been known to fly 45 miles an hour for eight hours in succession; of course the longer the distance the slower the rate.

The most interesting service that has ever been performed by these homing pigeons, and a service which bears most strongly upon their use for military purposes, was the employment that they were put to during the siege of Paris; when that city was surrounded by the German forces, and all ordinary means of intercourse from without were cut off, communication could easily be made from the inside of Paris to the outside by means of balloons, but the difficulty was to get messages conveyed from the outside to the inside. It so happened that there were two Colombophile Societies in Paris at that time, and they had about 400 birds belonging to the members, who immediately placed their pigeons at the disposal of the Government, and every balloon that went out, took with it a certain number of *voyageur* pigeons. They were not particularly good birds, as the members of the societies had not practised their birds to anything like the distance flown by the Belgian amateurs; but still they were birds capable of flying back to Paris, forty or sixty, or perhaps a hundred miles. The experiment was tried rather roughly, but still it succeeded; for the pigeons that went out brought back despatches of considerable length, printed in the first instance on small pieces of paper. I have here one of those earliest despatches in a cipher consisting of numbers; it is signed by M. Tachard, who at that time was the French ambassador in Brussels. These despatches were in the first instance sent to Tours, one of the nearest towns to Paris which was not invested by the German Army, and the pigeons brought out of Paris by the balloons, were liberated in the same town, and flew into Paris with the papers attached. In addition to the government cipher a number of letters were set up in type, and both M. Tachard's despatch and the letters were micro-photographed, and thus, in this small compass, were attached to the pigeons. Shortly after, M. Dagron, a celebrated photographer, placed his services at the disposal of the Government, and the pigeon post was organized. I have here the bill of the Government regulations, issued from the General Post Office, London, dated Nov. 16th, 1870. The letters for despatch into Paris, by pigeons, were to be sent open, and were at once forwarded by our postal authorities, to Tours, where they were immediately set up in type, and micro-photographed on thin films of collodion; of these films one, containing upwards of 3,000 different communications, each limited to twenty words, weighs only two grains. Thus prepared these films were rolled up tightly, placed in a very small quill, and tied to the feathers in the tail of the pigeon, which was then let off. Tours being only 40 miles from Paris, the flight was a mere bagatelle to a good bird. If the weather had been fine, and the pigeons had been good, all of them would have got back to Paris; but some did not return, so duplicates were sent, all consecutively numbered, until the French postal authorities at Tours received an intimation by balloon, that they had been received.

So exceedingly light were these films, that one pigeon could have carried the whole of the communications that went into Paris during the siege, amounting to 300,000 letters.

During the siege of Paris, 64 balloons left the city, conveying in addition to the æronauts, 363 pigeons, and 3,000,000 letters. Of the number of pigeons that were taken out, only 57 returned. The microscopic despatches taken in by these 57 pigeons would, if printed, have formed a bulky octavo volume.

I would now call your attention to the work that has been done in England with pigeons, since the siege of Paris. Perhaps the most important application of the homing power of these birds, is that with which I have been entrusted by the Elder Brethren of the Trinity House. In consequence of the wreck of the "Deutschland," off Harwich, some time ago, and the great loss of life that took place there, the Elder Brethren thought it desirable to attempt to make communication from the light-ships to the shore. Telegraphic communication with the light-ships is, I believe, impossible. The light-ships are moored by long chain cables, and swing with the tide, which arrangement is incompatible with the integrity of electric communication. Rockets are only available at night, and in clear weather. Flags are only to be seen by day, and some of these light-ships are out of sight of land, as is that on the Kentish Knock, where the "Deutschland" was wrecked. It was thought that pigeons might be made available, and in consequence I am conducting an experiment of this nature. The place that has been selected for the experiment is Harwich. In this town is an old unused light-house, now no longer required. This has been placed at my disposal, and I have now there a good stock of young pigeons, the object being to send some half-dozen or more to each of the light-ships, and then, when any message is required to be communicated to the shore, certain letters taken from the maritime code of signals will be stamped on the wing of the pigeon; for instance, "H B" may mean "Send a lifeboat," and so forth. In no case will more than three letters be required. We think it will be better to allow the sailors to stamp certain letters on the wings of the pigeons, and then liberate them, than to attempt to instruct them to tie messages round the legs of the birds, for this is rather a delicate matter; whereas they will have no difficulty in using a stamp containing certain type letters. When the bird is liberated, it will return to its home in Harwich, be caught, the message read and acted upon.

These light-ship birds will convey messages of wrecks and so forth to the light-houses on shore, so that the life-boat might be sent to either of the light-ships as required. Had there been on board the Kentish Knock light-ship, at the time of the wreck of the "Deutschland," half-a-dozen pigeons, they could have been liberated, they would have gone to Harwich with the message, the life-boat could have gone out immediately, and no doubt the majority of those lives that were lost would have been saved; at least, that is the theory on which we are working.

Another use which is made of these birds in England is for police purposes. I find that the Superintendent of the County Police at Ipswich, which is near to Harwich, has a staff of these birds. The police usually drive out into the country in small light carts, and take with them some trained pigeons. Supposing a constable in a part of the country far removed from any electric telegraph, wants assistance, or that he requires to make any communication to the head office, he writes his message on a piece of paper, ties it with a piece of thread round the leg of the pigeon, liberates the bird, and in the course of a few minutes or half-an-hour (it must be a large county that a pigeon could not fly over in half-an-hour) the intelligence is at the head-office, and the assistance can be sent, or the information be used.

With regard to the application of these capacities of the bird to military purposes, it is simply carrying out the same idea endeavoured to be carried out at the present time at the light-ship at Harwich. This use has already been achieved by the Germans. Seeing the utility of the pigeons to the besieged Parisians, they have organized a pigeon service at their own fortresses, and I believe there is not now an important fortress in Germany, and certainly none in France, that has not its flight of homing pigeons. Old birds are procured, and shut up in aviaries to breed. When they have bred, the young ones can be flown, which would be impossible with the parents. If you take this bird for instance, which has flown twice from London to Brussels, and shut it up two or three years in a large aviary where there is good room to fly and maintain its strength, the bird would rear its young, and go on living just as happily as though flying. But if let out, it would rise in the air, possibly describe two or three large circles, perhaps not even one, and would go away in search of Brussels. Nay, if you were to take that bird, and cut off half its feathers, and then allow its power of flight to be gradually restored, as it acquired new feathers by moulting, it would get to the top of the house; then as it produced new feathers, it would fly round with the other pigeons, and as soon as it had procured its full complement of feathers, your place would probably know it no more. The bird might not have strength to get across the sea to Brussels, but it would make the attempt. It is evidently impossible, therefore, to buy a number of these pigeons, and to set up a flock for immediate use. To do this a commencement must be made with young pigeons that have not flown, or a number of birds must be allowed to breed in a large aviary, and the young ones reared, liberated, and trained.

In the case of a fortress, the young birds would have been trained to fly back to their home first from short distances, then two or three miles, then five or six miles, and so on, until at last you had them returning from distances of 30, 40, 50 or even 60 miles, and then up to

100 miles. Now suppose the fortress besieged, then before its complete investiture you would send out 30 or 40 pigeons; or, even after its complete investiture, you could organize and send out some pigeons by a small balloon, to bring back messages when liberated.

The value of homing pigeons, in such places as Jersey or Guernsey, in case of a war with any European power that had the means of cutting off telegraphic communication, would be inestimable.

Let us suppose that we expected to see an enemy's fleet in the channel. Of course swift steaming vessels would be sent out to watch this fleet, and to bring the intelligence back to England; but to get the intelligence to England, it would require the vessels to leave off watching the fleet, and to come back at an expense of several hours or days sailing, to Portsmouth or Southampton, to deliver that intelligence. But supposing on the other hand that these vessels sent out to watch the fleet, had on board a basket of pigeons duly trained, intelligence could be sent off from hour to hour, and from day to day, the frigates stopping all the while to watch the enemy.

When Captain Webb swam across the Channel, an illustration was afforded of the manner in which these homing birds can be used. The steamboat that went out to watch him took a number of *voyageur* pigeons from the pigeon fanciers at Folkestone; and hour by hour as Captain Webb went on, his rate of progress was brought back to England by these birds.

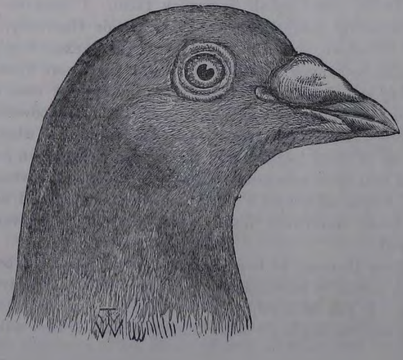
It appears to me that if the Germans have thought it necessary to establish *voyageur* pigeons in their fortresses, surely it must be also desirable for the English to employ them. I imagine that there must be many localities, such as Jersey or Guernsey, and other places, to which, or from which, it would be exceedingly desirable to be able to convey messages supposing they were invested. Perhaps they would be less available to us in England than they would be to the Germans, or the French, or the continental powers generally, but surely there must be, or may be, many situations where their use would be of great importance. Of course in our own country it is obvious that their greatest value would be for those vessels that go out to watch an enemy's fleet, but there may be, I should say, many other conditions under which they could be very usefully employed.

I believe theories with regard to their utility have been started that are perfectly incompatible with the nature of the bird's homing faculty. It has been said that pigeon houses could be taken with armies, and the birds on being liberated could fly back with messages to their movable homes. This is all nonsense. It would be quite impracticable to organize sets of pigeons and pigeon houses after this fashion.

The only mode in which pigeons can be used is in conveying messages back to the places where they have been reared. It has been objected by some that the birds will be of no use in a fog. The same objection might be made to the use of signals, or flags at night. We have in these cases to avail ourselves of all the means which are possible, and under certain circumstances a pigeon carrying long despatches and long messages is really more valuable than any other mode of communication.

I have endeavoured to show you the circumstances under which *voyageur* pigeons can be used, and the circumstances under which alone they are applicable; and I want particularly to remove the impression that the pigeon is capable of being used under all circumstances. I think that there may be conditions under which they may be used with advantage in connection with military operations, and with this feeling I have endeavoured to place them before you, and I thank you for your attention to what I have had to say.

Head of Homing Pigeon.



The engraving shows the true type of head of the *voyageur* or homing pigeon, as distinguished from the long faced English fancy breed known as the Carrier. The bird whose portrait is engraved has flown several times from Brussels to London.

W. B. TEGETMEIER.

A question was asked as to the percentage of birds which was lost from being shot, or from being attacked by birds of prey?

Mr. Tegetmeier replied, that the pigeons flew so high as to be practically out of the range of fowling pieces, and that in England the loss from birds of prey was very small. There were very few places where hawks were common, and the preservation of game in this country was so much attended to that there was very little loss from birds of prey. In Belgium prizes were given for the destruction of hawks.

Colonel Hassard in expressing the thanks of the audience to Mr. Tegetmeier, wished to supplement it by a few remarks: Commander Wharton, of H.M.S. "Fawn," lately at Sheerness, thought that pigeons might be used in surveying service, in which that ship is employed, and had taken some with him for that purpose; baskets had been specially made to go under the thwarts of the boat, and pigeons could thus be carried. In case a boat could not return at night a notice could be previously sent by bird to the ship. To what an extent this can be done is difficult to say, but from statements of other naval officers with whom he had had communication it appeared that pigeons did know their own ship, returning to it before night; and that when in harbour if their ship was suddenly sent off anywhere during their absence, on its return to that harbour they returned to the ship. Of course an isolated surveying ship would be a conspicuous mark, and if not changing its position a great number of miles a day, he thought these pigeons might be used. He had had a letter from Commander Wharton who has succeeded in partially training a young bird who returned to his ship; he also wished to state that in 1852-3, when quartered in the Channel Islands, when communication was only once in ten days (no telegraph then existing), he had used pigeons with good effect for military purposes—to obtain information required. Whenever he was called upon he would be prepared to furnish a detailed scheme for their uses at different fortresses, &c., round the coast of England.

$6\frac{1}{2}$-inch plates; and also with the effect of Round 2043 (see Part II. at page 74, No. 2 of this volume), in which the same nature of projectile, with 13,080 foot tons of energy, got its point through three $6\frac{1}{2}$-inch plates and one inch into a fourth plate, it will be seen how large a share of the energy in this shot was lost upon the target.

It was thought by some of those who witnessed the experiment that the loose way in which the 3-inch plate was held to the face of the target had something to do with the failure of the shot on this occasion: but that explanation cannot be accepted, because, although that plate did fall off in course of the round, as was quite expected, still it did not move sideways so as to throw the shot off its balance, as was clearly seen by the way in which the bulge on its back fitted into the dish on the face of the front $6\frac{1}{2}$-inch plate.

The real explanation is that the material of the shot was bad in quality, and this is fully borne out by the appearance of the metal of the fractured shot, as well as by the great number of small pieces into which it was broken.

The only value of the experiment appears to consist in its showing how much depends upon the manufacture of Palliser projectiles being maintained at a uniform and high standard, as regards strength and hardness of metal in both head and body.

The failure of this round is much to be regretted because it is very important that we should know early what is the least amount of "plate upon plate" armour that will give protection against the battering shell of the 38-ton gun. However, it is hoped that No. 40 Target will yet afford space for another round to solve the question.

The Chambered 38-ton Gun against a Single Unbacked Iron Armour Plate, $16\frac{1}{2}$ Inches Thick.

The experiment now to be recorded was happily attended with results quite opposite in character to those of the last one.

In summing up the results of the trials with the 80-ton gun against No. 41 Target, in Part II. of this subject (see No. 2 of the present volume), it was shown that further experience as to the comparative resistances of the "plate upon plate" and "single plate" structures was very much needed.

The information upon which we had up to that time principally relied in dealing with this subject was that obtained in the trials of 1867-8, as recorded in Paper XII. of Volume XVI., and Paper XV.

of Volume XVII., of the *Professional Papers*, and the general conclusions derived from those trials were briefly these :—

1. That assuming the energy necessary for a 7-inch Palliser shot to perforate a 7-inch plate to be represented by 100, the energies sufficient for similar shot to perforate the same thickness of armour arranged in two or three layers would be as 96 and 89 respectively.

2. That these relative figures were partly verified by comparing the effect of 9-inch Palliser shot upon targets composed of two 5-inch plates and single 10-inch plates.

3. That in some comparative trials of targets consisting of three 5-inch plates and single 15-inch plates, the latter were beaten as regards resistance to repeated blows, and were only slightly superior as regards a single blow from the heaviest gun of the period.

When, however, it is remembered that these trials were made with shot striking with energies varying from 1000 to 4400 foot tons, and that now we have to deal with blows represented by the force of more than 30,000 foot tons, the necessity for obtaining data upon which to base fresh calculations becomes at once apparent.

Having obtained in Round 2039, as reported in Part I., No. 1 of this volume, so exact a measure of the penetrative power of the 38-ton gun upon a three-plate target, it was thought that we could not do better than use this result as our datum, and endeavour to obtain an equivalent result with the same gun upon a single plate. Accordingly, after due consideration of former trials, it was settled that the single plate for comparison should be $16\frac{1}{2}$ inches thick, and an iron armour-plate of this thickness, measuring 8 ft. by 8 ft., was ordered.

The final pile from which this plate was rolled was made up of seven moulds, and was 9 ft. 6 ins. long by 8 ft. 4 ins. wide, by $23\frac{1}{2}$ inches in height. The bottom mould in the furnace was 6 ins. thick, the other six moulds making up the remaining height of $17\frac{1}{2}$ inches. It may be mentioned here that the side of a plate which is undermost in the furnace, and, therefore, in the rolls also, is invariably made the back of the finished armour plate, because the upper side in cooling becomes rather the harder of the two.

The pile, as it went into the furnace, weighed about 33 tons. It was in the furnace 30 hours. The finished plate, as set up at Shoeburyness, weighed $18\frac{3}{4}$ tons.

For the trial the plate rested against supports at its top and bottom edges to prevent its being driven back, and it was held from falling forwards by two bolts through its upper corners.

The 38-ton chambered gun was used for the trial, and it was placed at 65 yards from the plate.

The date of the trial was 1st August, 1877, and the round was numbered 2069.

The projectile was a service Palliser shell, 33·18 inches long, and 12·43 inches in diameter over the body, weighted with sand up to 817 lbs., including a gas check which weighed 11 lbs. 9 oz.

The charge used was 175 lbs. of P^2 powder, and this gave a velocity at the target of 1,410 feet per second, making the blow equivalent to about 11,260 foot tons, or rather less than that in Round 2039 which was equal to about 11,400 foot tons.

The shell struck 2 ft. 10 ins. from the left ridge, and 2 ft. 11 ins. from the top, and passed through the plate.

It made a round hole, 13 inches in diameter, and perpendicular to the face of the plate, with a lip from 2 inches to 3 inches round the front edge. It broke off the moulds on the back of the plate over an area of 2 ft. 9 ins. by 2 ft. 9 ins., and to a depth at one part of $7\frac{1}{2}$ inches. The welds of three moulds could be seen in the fractured part. From the left edge of the plate to a point near the shot hole a crack was formed extending through the whole thickness of the plate on its edge, and gaping from $\frac{1}{4}$-inch to $\frac{3}{8}$-inch.

The plate was buckled about $\frac{1}{4}$-inch on a horizontal line across its face, but only $\frac{1}{16}$-inch in a vertical line.

The plate was moved forward about $5\frac{1}{2}$ inches by the blows.

The shell was broken up into a great number of pieces in passing through, but still every part of it did get through, even including the gas check.

The quality of the metal of the shell was equal to the average of service Palliser projectiles.

An old armour-plated target in rear was a good deal scored, and indented in some instances to a depth of from $\frac{1}{2}$-inch to $\frac{3}{4}$-inch, by the pieces of the shell. A 6-inch double "paunch" mantlet which had been hung up behind the target was cut through, and a good deal damaged, and some timbers of the supports in rear were also cut through.

The point of the shell was found entire.

Comparing this result with that of round 2039, it will be seen that the shell on this occasion pierced the $16\frac{1}{2}$-inch plate with some more force to spare than that which the corresponding shell had in it after piercing No. 40 Target in its original state. Therefore, I think it may now be fairly assumed that a solid rolled iron armour-plate of 17 inches or $17\frac{1}{2}$ inches in thickness is equal, as regards resistance to perforation, to three $6\frac{1}{2}$-inch iron plates separated by 5-inch layers of teak.

Also, this experiment, so far as it goes, seems to bear out the statement, made in Part II. of this subject, as to the equivalent for three $8\frac{1}{2}$-inch plates, with teak between them, being probably 23 inches of solid iron plate.

For so large a plate, the heaviest and largest section ever rolled in England, the condition of the iron was quite satisfactory, and the welding good; showing that the treatment of large masses in the furnace is now better understood than it was 10 years ago, and that the means of handling them in the rolls have also been improved.

Palliser Shell at Armour-Plates separated from Masonry, and from other Armour-Plates, by Void Spaces.

In continuation of this subject, as noticed in Part II. (see No. 2 of this volume), the round against a plate standing a short distance in advance of a masonry wall, and also one against a plate at a reduced distance from another plate, can now be reported.

Taking first the masonry experiment, which took place at Shoeburyness, on the 20th of July, 1877, the wall used for the purpose was not so solid and massive as could have been wished, but it was the best that could be extemporized with the means at our disposal. It consisted of a mass of granite 14 ft. 9 ins. in frontage, 7 ft. 6 ins. high, and 3 ft. 6 ins. deep, built against the face of an old brick and Portland cement concrete wall with a good number of heavy iron cramps in it, which had formed part of a large structure built for experiments in 1864.

This brick and concrete wall was 7 ft. 6 ins. thick, making, therefore, with the granite wall in front, a total thickness of masonry of 11 ft.

The weak part of the arrangement was that of the new granite work being built without much top weight or side support, and without bond, or cramps, or dowels of any kind. Still the stone which was to receive the first shock after the shot had got through the armour plate was a good sized block, measuring 5 ft. by 4 ft. on the face, and 3 ft. 6 ins. in depth, and weighed, therefore, about 5 tons. The plate used was an old iron one, with three shot holes already in it. It was 7 ft. 6 ins. by 3 ft. 9 ins., and $4\frac{1}{2}$ inches thick. It was set up on end at a distance of 1 ft. 6 ins. from the face of the granite, and was merely blocked out from it by pieces of iron bar.

The gun used was the 38-ton gun, at 50 yards, and the projectile was the service Palliser shell, the charge being so arranged as to make the round correspond as closely as possible with the two previous rounds from this gun at void space targets, already reported.

The round was numbered 2068.

The shell struck 3 ft. 3 ins. from the bottom of the $4\frac{1}{2}$-inch plate, and 1 ft. 3 ins. from its left edge, making a clean hole 13·5 to 13·8 inches in diameter, and bulging the plate outwards 6 inches on its right edge. The plate was, of course, knocked down.

The granite wall was completely wrecked; indeed, with the exception of two or three stones near its ends, nothing of it was left standing. The centre stone, already described as having been placed to receive the shot, was ground almost to powder. The brick and concrete wall in rear was cleaved asunder, with a great vertical rent about 1 foot wide in parts, and the whole structure was much knocked about, and displaced in large masses.

At first sight it appeared as if the shell had not been injured by the plate, and had passed entire into the very heart of the masonry in rear. But such was soon found not to have been the case. On turning over the pounded granite of the wall a great number of small pieces of the shell were found very near to the front, and the point of the shell itself, about 4 inches long, was recovered at a depth of only 3 ft. 3 ins. in from the original face of the granite wall. In fact, there is every reason to believe that the whole shell broke up small on first striking the granite, upwards of 240lbs. weight of small pieces of its head and body having been dug out at no great depth from the front.

Here, then, we have the double blow upon a detached plate and a granite wall producing an effect upon a Palliser shell approaching nearly to that obtained in the rounds against armour-plates with void spaces between them, already described.

That the breaking up of the shell was due to the iron plate is evident from the fact of a similar shell, in Round 2040 (see Part II.), having passed unbroken through 11 feet of masonry, of which about half was granite; and further, that it was due to the plate being *detached* may be inferred from the results of other experiments—chiefly those of 1869—reported at page 265, Vol.

XVIII., of *Professional Papers*, when 7-inch Palliser cored shot were used against $4\frac{1}{2}$-inch armour-plates, which were placed at a short distance in front of a granite wall, the 15-inch interval between the plates and the wall being filled with concrete and other substances, and none of the shot broke up small.

As already intimated, the granite wall used in the present trial was very inferior to the masonry of an actual work of defence, on account of the absence of bond and want of continuity in the structure, and due allowance should be made for this in drawing conclusions from the round.

The only other trial of void space targets to be noticed in this paper is one that was made on the same date as the last, to carry out the intention, expressed in Part II., of repeating Round 2046 with a reduced distance between the 4-inch and 10-inch plates.

For this purpose the 4-inch plate, which had been used before in similar trials, was set up 1 ft. 6 ins. in advance of a small piece of 10-inch plate, measuring 3 ft. 8 ins. by 3 ft. 8 ins., which had already got one shot hole in it. Neither plate was held securely.

The 38-ton gun was again used, the charge being so arranged that the blow should be equal to those delivered against the previous void space targets.

The number of the round is 2070.

The shell struck the 4-inch plate in a sound part, 2 ft. 5 ins. from the bottom, and 2 ft. 7 ins. from the right edge, making a round hole 13 inches in diameter. It threw the plate down.

The shell then struck the 10-inch plate, 2 ft. 4 ins. from the bottom, and 1 ft. 2 ins. from the left edge. The point indented the plate to a depth of $5\frac{1}{2}$ ins., splitting the plate through the indent and through the former shot hole, and breaking it into several pieces, some of which were thrown to a considerable distance. Although the point of the shell appears to have been unbroken when making the indent in the 10-inch plate, a considerable quantity of both head and body remained sticking on the face of this plate in the form of "splash," but certainly in less quantity than in the former trials of targets consisting of two armour-plates with void intervals between them. Little importance should be attached to the breaking up of the 10-inch plate in this round, because, from its small size and previous injuries, its separation represents no great amount of work.

From this trial it would appear that, at any rate with the 38-ton gun projectile, the interval of 1 ft. 6 ins. is scarcely sufficient to admiof the work of disintegration of the shell being carried so far as to relieve the back armour of that large share of the total work in the shell which it escaped in the rounds when the intervals were three and four times as great.

In thus noticing these void space trials it is not intended to convey the impression that they are likely to lead to any immediate results as regards the application of armour to works of fortification, for there are, in the first place, practical objections to the use of armour-plates without backing on account of their being under that condition more liable to break up than when bedded against moderately compressible substances. Also, there is the difficulty of guarding against the effect of heavy shell carrying large bursting charges of, perhaps, explosives even more violent in their action than gunpowder, into the vacant intervals. Besides, there is nothing yet to show that steel, or even improved chilled iron projectiles, would fail against these structures.

Beyond, therefore, being curious, and interesting from a scientific point of view, it is thought that the chief value of these results lies in their having shown that the limit of endurance of the service Palliser shell had been much nearer approached in the trials of late years than might otherwise have been suspected, and this will be of no slight advantage if it should lead to measures for the improvement of our armour-piercing projectiles.

Compound Steel and Iron Armour Plates.

When speaking of the trials for the Italian Government made last year at Spezia (see Part II. of this subject), attention was drawn to the comparative facility with which heavy steel plates were broken to pieces by Palliser projectiles, notwithstanding that they proved themselves superior to ordinary iron armour plates in resisting perforation by a single shell.

In this country these results attracted a good deal of attention, and the conclusions drawn from them were not generally favourable to the use of steel armour as it was applied to the Spezia targets. Still, it was plain that if by any means the advantage of the greater resistance to perforation offered by steel could be combined with the greater tenacity shown by wrought iron under sudden blows, an important step would be gained in the manufacture of armour plates for use, at any rate, in floating structures.

Accordingly, the English armour plate makers set themselves to work upon this problem; and, to assist them in their operations, they were allowed to send their sample plates, as they made them, to Shoeburyness for proof, under the system there established for fortification purposes.

Although these operations have not yet passed beyond the experimental and preliminary stage, it may still not be amiss to give here a short account of what has been done in the matter up to the present time.

The first trials were made with small plates of soft steel, produced by the Bessemer process, and rolled direct from the ingots. Of these one tempered in water at red heat gave better results than those untempered; but still, at the best, there was too much tendency to crack in these plates, and not sufficient hardness to break up the heads of the Palliser shell.

Another plate made from a Bessemer ingot of soft steel, squeezed in a press and afterwards rolled, and cooled in sand, broke up into a number of pieces.

Also a 5-inch iron plate carburized on its face to a depth of $\frac{3}{4}$-inch, and on its back to a depth of $\frac{1}{2}$-inch, in a converting furnace, broke up unsatisfactorily.

At a subsequent period an attempt was again made to convert the face of a 5-inch iron plate into steel: but, in this case also, the back became carburized as well as the front, the former to a depth of $\frac{1}{2}$-inch, the latter to a depth of $\frac{1}{4}$-inch, and the plate did not give good results at Shoeburyness.

After this the process of welding steel and iron together into a compound mass was once more taken up.

The object to be gained by this combination, in the case of armour plates, is simply that of presenting to the projectile a hard face, against which its force may be expended, and itself broken up, if possible, at an early stage of its work upon the armour; while, in order to counteract the effect which sudden blows will always have upon hard steel, or rather in order to hold the steel together after it may have been cracked by the shot, a soft and ductile wrought iron back is provided.

On referring to Vol. XVI. of the *Professional Papers*, Paper XII., it will be seen that an extensive series of experiments took place at Shoeburyness, in 1867, with plates of steel and iron welded together, but the general result was that the compound plates could not compete with the ordinary soft rolled iron armour.

The difficulty then experienced was that which, it is well known, has always attended the welding of iron to steel, namely, that of dealing with two kinds of metal, which weld at different temperatures; which difficulty is aggravated in the case of the two metals containing widely different proportions of carbon, as in *hard* steel having to be united to *soft* wrought iron.

The failure of the steel and iron plates in 1867 brought such manufacturing difficulties to light that no further attempts were made for some time in that direction, at any rate with masses of metal of any considerable size.

But of late years steel and wrought iron have been very perfectly welded by pouring the steel in a molten state on to the iron, previously raised to a white heat; and this process has, I believe, been successfully applied to the manufacture of railway material, and to other purposes.

Improving upon this mode of manufacture a process has been devised at the works of Messrs. Cammell and Co., of Sheffield, which Mr. G. Wilson, the managing director of the firm, has obligingly described to me in the following terms.

"Since the trials at Spezia the inherent difficulty in welding large masses of steel and iron has been overcome by Mr. Alexander Wilson, by pouring steel in the melted state upon the surface of an iron plate when it has been heated to a good red heat. The temperature of the molten steel being much in excess of the welding heat of iron, the surface of the heated iron plate becomes partially fuzed by the overlying liquid steel, and thus a complete union or weld between the two metals is obtained—there being practically no limit to the masses of metal used.

"In this case the weld is not limited to a simple line marking the difference between the steel and the iron, as is the case in all ordinary welds, but a third metal or semi-steel is formed between the two, varying in thickness from $\frac{1}{8}$-inch to $\frac{3}{16}$-inch, by the carbon of the steel running into the iron, and through the formation of this semi-steel, the two metals are joined together inseparably, or, in other words, the steel has run gradually into the fibrous iron and the iron into the steel.

"Experiments have been made to ascertain the relative strength of this weld, and on every occasion the iron only has been torn asunder out of the solid, while the weld itself has remained intact."

Two small armour plates made upon this plan were sent by Messrs. Cammell for test at Shoeburyness in July last. Each measured 3 ft. 6 ins. by 3 ft. 10 ins., and 9 inches in thickness. One had a 5-inch face of hard steel, containing ·64 per cent. of carbon, and a 4-inch wrought iron back, and was hammered. The other had a $4\frac{1}{4}$-inch face of somewhat softer steel, containing ·48 per cent. of carbon, and a $4\frac{3}{4}$-inch back of wrought iron, and was rolled. They were made by heating 7-inch rolled iron plates to a good red heat, and quickly transferring them to a cast iron mould or box. Molten steel was then poured upon the wrought iron to a depth of 8 inches, so that the combined ingot thus formed was 15 inches in thickness. The masses were then reduced, by hammering and rolling as above-mentioned, to the finished thickness of 9 inches. The slight difference between the thickness of the steel in the two plates was accidental, or perhaps the difficulty of judging where the division between the steel and iron occurred will account for the difference of thicknesses recorded.

They were tried with 7-inch service Palliser shot, weighing 113 lbs., and fired with 30 lbs. of pebble powder, at 30 yards.

With regard to the first, that is the one with the hard steel face, the indent was only 3·2 inches deep. The shell broke up in its head as well as in its body, and the plate was scored by it all over its face.

The fragments of the shot were hot when picked up. Five cracks radiating from the indent were formed in the plate. One of these was 7 inches deep as measured on the edge of the plate, another 5 inches, the other three were fine cracks and of less depth. The area of the shot mark on the face of the plate was $9\frac{1}{2}$ inches in diameter. In rear the bulge was local, and only $\frac{2}{10}$-inch high, and there were no cracks at all.

The welding of the steel to the iron was very perfect, and showed no signs of giving way in any part.

The slightness of the indent is remarkable. The corresponding indent in a 9-inch wrought iron plate of best quality, under similar circumstances, is generally from $12\frac{1}{4}$ inches to complete perforation. By the completeness of the welding the effect of the cracking of the steel was neutralized to some extent by the wrought iron, while the hardness of the steel led to the breaking-up of the projectile, and the consequent loss of work upon the plate.

With regard to the second of these plates, namely, that with the soft steel face, the shell in this case made an indent 5·45 inches deep. The head of the shell was much broken, and the body was also broken up small, but the destruction of this projectile was not so complete as was that of the shell against the other plate. In this instance there were four radiating cracks, $7\frac{1}{2}$ inches, 4·7 inches, 4·7 inches, and 4·5 inches deep from the face respectively. In rear, the local bulge was ·85-inch high, and there were faint cracks, with a gape of $\frac{1}{2}$-inch at the widest part, on the bulge. The welding of the steel to the iron was undisturbed in this case also.

It may be mentioned that Messrs. Cammell & Co. made another small 9-inch plate about this time, which was composed of a 5-inch hard steel centre between 2-inch soft steel at front and back; but this plate, although it was only indented 4·8 inches deep by the 7-inch shell with 30 lbs. of pebble powder, broke up into four pieces. The head of the shell in this instance remained entire, but the body was splashed against the plate. When first picked up the head was cool, but it grew warm afterwards.

This plate was made by casting the steel in layers, each layer being allowed to set before the next was run upon it, and the mass was afterwards rolled down to its finished thickness. From the appearance of the fractures at proof, the hard and soft steels seem to have become fused together, and the metal was homogeneous throughout.

Messrs. Brown and Co., of Sheffield, also made two small plates by heating equal masses of hard Bessemer steel and wrought iron in an ordinary furnace, and rolling them down to five inches in thickness, borax being used as a flux. Thus the plates were half of steel, containing 0·5 per cent. and half of wrought iron. One of these plates was hardened in water, and the other was unhardened.

The indent from a 7-inch Palliser shell, weighing 113 lbs, fired with $8\frac{1}{2}$ lbs. of R.L.G. powder, at the hardened plate, at 30 yards, was 3·35 inches, or just half the depth of the usual indent from the same blow on a 5-inch rolled iron armour plate of A 1 quality. A 7-inch shell fired with 25 lbs. of pebble powder got its point through this plate. The welding of the steel to the iron was not so perfect as in the 9-inch plates lately described. The head of the shell remained whole, but the body broke up small.

The plate that was unhardened was indented 3·4 inches, as against 3·35 inches in the hardened one. A 7-inch shell, fired with 20 lbs. of pebble powder, penetrated this plate and broke it in two. The welding was somewhat better in this case, but neither of the plates was altogether satisfactory. It was thought that the resistance offered by these plates to perforation was about equal to that of a soft iron armour plate 8 inches thick.

Just as this account was completed Messrs. Brown and Co. sent for trial another compound plate, made in the following manner. A 9-inch rolled iron armour plate was laid in an ordinary furnace, and upon this was placed a wrought iron frame, made of bar, 7 inches high and 4 inches wide, running all round the plate close to its edges. When at a red heat the plate with its frame still upon it was brought out of the furnace, and hard Bessemer steel, containing 0·5 per cent. of carbon, was run in a molten state upon the iron armour until the tank formed by the frame was full to the brim. By the heat imparted to the wrought iron by the steel the frame and plate were brought to welding heat and united, and the steel and iron were also welded as in the other experimental plates already described. The mass was then allowed to cool, and was afterwards reheated and rolled down to a 9-inch plate, of which the front four inches were of steel. It was then cut to the usual dimensions of proof plates, namely, 3 ft. 10 ins. by 3 ft. 8 ins.

The 7-inch Palliser shell, fired with 30 lbs. of pebble powder, at 30 yards, indented the plate to a depth of 4·5 inches, and raised a bulge on the back $\frac{3}{10}$-inch high and 13 inches across. There were six radial cracks formed through the steel, stopping at the wrought iron frame at the edge of the plate. The head and body of the shell were broken into small pieces.

These being the principal results of the preliminary trials, the manufacturers have, on the experience thus gained, made some large compound plates for the Admiralty, for comparison with rolled iron plates and steel plates, and it is hoped that the trial of them will come off before very long.

T. INGLIS,

9th November, 1877. COLONEL, R.E.

PAPER XIX.

THE CYCLOSCOPE.

By Lieut. G. S. Clarke, R.E.

The problem of devising a means of ascertaining at any moment the speed of a revolving body has received numerous more or less successful solutions. If a trustworthy constant rotary motion can be obtained to be used as a standard, an epicyclic train can be made to give the desired indications. There is, however, a great difficulty in obtaining a motion which will remain constant even for a short period of time. Again, a small centrifugal pump will maintain a greater or less column of water as the speed at which it it driven increases or diminishes. Further, in the strophometer, an instrument which has been used successfully on some ships of war, two heavy balls linked to a vertical axis, like those of the ordinary governor, tend to fly outwards in proportion to the square of their velocity, and, in so doing, move an index arm traversing over a figured dial.

In the instrument about to be described, which has been devised by Professor H. McLeod and the writer, the standard motion is vibratory, and is given by a tuning fork, or reed, the period of which, though not absolutely constant as will be noticed hereafter, is liable to but slight alteration.

If a pointer attached to one limb of a tuning fork is placed so as just to touch a smoked drum driven by the machine whose speed is to be measured, it will trace out a wave line of the form shown in *Fig.* 1, *Plate* I.

The portion from *a* to *b* is traced during one vibration of the fork and the distance apart of the crests of adjacent waves will depend upon the velocity of the drum, becoming greater as that velocity increases. Suppose that the perimeter of the drum is 10″, the period of the fork 60 vibrations per second, and that five complete waves occur in a length of one inch of perimeter. Then evidently $\frac{1}{10}$ of a complete revolution takes place in $\frac{1}{12}$ of a second. The speed of the drum is, therefore, 72 rotations per minute.

Practical difficulties would arise in utilizing this method, and, moreover, it would be necessary to stop the drum in order to make an observation, and then either to measure off on the perimeter of the drum the length occupied by a given number of vibrations, or to count up the number of vibrations taking place in a given length of perimeter. This operation would in most cases be too tedious. An optical method has therefore been adopted, which has been found to give excellent results.

If a number of dots at equal intervals are viewed in a mirror, or through a lens attached to a tuning fork, then, in virtue of the retention of their images on the retina the dots will appear as straight lines. Thus the images of the dots shown in *Fig.* 2 will appear drawn out into the lines shown in *Fig.* 3, if the fork is so placed that the motion of the images is at right angles to a line through the dots.

If, further, a motion is given to the dots at right angles to the direction of vibration of their images, the two combined rectilinear motions will produce the appearance of a sinous line, or wave form.

The height of the wave will depend on the amplitude of the vibration of the fork, while the wave-length will depend on the relation of the speed of the dots to the period of the fork. The greater the speed of translation of the dots becomes, the greater will be the wave-length.

If certain exact ratios obtain between the velocity of the dots and the period of the fork, the waves formed will be absolutely stationary. If the velocity of the dots is slightly greater or less than that required for the fulfilment of these ratios, the wave will be the same in form as that which the exact ratio would give, but it will have a slow progressive motion. This progressive motion will be in the same direction as that in which the dots move if the velocity of the latter is too great, and in the reverse direction if it is too small for the exact ratios.

The laws governing the ratios on which the formation of stationary waves depends may be stated as follows :—

If the velocity of the dots is such that the time occupied by each dot in passing over the interval between two adjacent dots, is exactly equal to the period of one complete vibration of the fork or reed, a single stationary wave (*Fig.* 4*a*) is produced.

If the time occupied by each dot in passing over *two* intervals is equal to the period of one complete vibration, the wave traced by the image of each dot will pass through the position of the adjacent dot, and as each dot will trace a wave of its own, a double wave (*Fig.* 5*a*) compounded of two single waves will result.

Again, if a complete vibration takes place in the time of passing of a dot over three or four intervals, triple and quadruple waves (*Figs.* 6*a*, *Plate* I., and 7*a*, *Plate* II.) will respectively be formed.

Similarly, waves compounded of five, six, seven, and eight waves may occur under suitable conditions as to the velocity of the dots. There is, in fact, theoretically, an infinite number of compound waves. The eighth compound wave has been actually observed; but the production and maintainance of the more complex forms requires a regularity of motion which it is very difficult to obtain.

It will be evident that waves of the same form as those above defined can be obtained with other velocities. Thus, if *two* complete vibrations occur in the time of passing of a dot over *one* interval, another single wave (*Fig.* 4*b*) is produced. Similarly, if *three* complete vibrations take place in the time of passing of a dot over *two* intervals a new double wave (*Fig.* 5*b*) results. Again, a triple wave (*Fig.* 6*b*) occurs when *two* complete vibrations occur in the time of passing of a dot over *three* intervals, and a quadruple wave (*Fig.* 7*b*) if *three* vibrations take place in the time of passing of a dot over *four* intervals. There is, theoretically, an infinity of series of waves, and an infinity of waves of the same form in each series.

The form of the wave determines at a glance the series to which it belongs, while differences of wave length and of brilliancy distinguish between waves of the same series.

The first or primary wave in each series (*Figs.* 4*a*, 5*a*, 6*a*) has the greatest brilliancy, while it requires the greatest velocity of the dots for its formation.

The laws of formation of the different waves may be stated as follows:

1.—*Single wave*, any whole number of complete vibrations in the time of passing of a dot over *one* interval.

2.—*Double wave*, 1, 3, 5, 7, etc., complete vibrations in the time of passing of a dot over *two* intervals. Any whole number of vibrations not divisible by 2.

3.—*Triple wave*, 1, 2, 4, 5, 7, etc., complete vibrations in the time of passing of a dot over *three* intervals. Any whole number of vibrations not divisible by 3.

4.—*Quadruple wave*, 1, 3, 5, 7, 9, etc., complete vibrations in the time of passing of a dot over *four* intervals. Any whole number of vibrations not divisible by 2 or 4.

And so on for more complex forms.

The above laws may also be expressed as follows :—Denoting the velocity of the dots required for the formation of the primary wave of the first series by unity ; the velocities required to produce other waves will be—

1st Series	$1, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}$ . . . . . .
2nd ,,	$2, \frac{2}{3}, \frac{2}{5}, \frac{2}{7}, \frac{2}{9}$ . . . . . .
3rd ,,	$3, \frac{3}{2}, \frac{3}{4}, \frac{3}{5}, \frac{3}{7}$ . . . . . .
4th ,,	$4, \frac{4}{3}, \frac{4}{5}, \frac{4}{7}, \frac{4}{9}$ . . . . . .
5th ,,	$5, \frac{5}{2}, \frac{5}{3}, \frac{5}{4}, \frac{5}{6}$ . . . . . .

It remains to show how the principles above laid down can be utilized in a practical form.

Suppose that a drum carrying 100 dots, equally spaced round its perimeter, rotates in front of a reed or fork, giving 60 complete vibrations per second, the latter being so placed that the images of the dots are displaced in a direction at right angles to their motion, or parallel to the axis of the drum. If then the drum is driven at such a speed that the primary single wave appears stationary, it will be evident that 60 dots per second, or 3600 per minute, must be passing in front of the vibrating lens or mirror, but as in one complete revolution of the drum 100 dots pass, the speed of the drum must be $\frac{3600}{100} = 36$ revolutions per minute. Again, if a primary double wave appears stationary the speed of the drum is evidently $\frac{2 \times 60 \times 60}{100} = 72$ per minute, while a primary triple stationary wave would require a velocity of $\frac{3 \times 60 \times 60}{100} = 108$ per minute, and so on. By referring to the above table the speed required to produce any other wave can be obtained. For practical purposes the primary double wave seems best adapted. Its form is easy to recognise, and its superior wave length and brilliancy serve to distinguish it from other waves of the same series. Moreover, a symmetrical form which gives bright points, or crossings along its centre line possesses advantages. If t is the number of complete vibrations of the fork or reed per second ; v the number of rotations per minute of the dotted drum, and n the number of dots ; then a stationary primary double wave will be produced, if

$$v = \frac{2\,t \times 60}{n}*.$$

From this equation v, n, or t can be found if two of them are known. If, therefore, it were required to read velocities of from 20 to 40 revolutions per minute, it would be necessary to place round the drum a series of rings of dots containing—

$$\frac{2\,t \times 60}{20}, \quad \frac{2\,t \times 60}{21}, \quad \frac{2\,t \times 60}{22}$$

etc., dots each. If then any ring, say the 5th from the ring corresponding to a velocity of 20, gave the stationary double wave, it would be certain that the speed of the drum was 25.

A practical difficulty arises, however, in placing such a series of dots round a drum, for instance, with a 60 fork, or reed, the perimeter of the drum would have to be divided into 342·8571 intervals, in order to obtain a stationary primary double wave with a velocity of 21 per minute, and, moreover, even if such a division were practicable, it would not be possible to read off speeds intermediate between whole numbers of rotations per minute, *e.g.*, $21\frac{1}{2}$. It becomes necessary, therefore, to adopt some other method.

If, instead of dots, equidistant lines are placed round a drum, parallel to its axis, and are observed through a slit attached to a fork, or reed, precisely similar waves to those above described are formed. A piece of paper is prepared by ruling lines as in *Fig.* 8, *Plate* II., which all converge in a point o, and pass through equidistant points on the line $a\ b$, and a rectangular portion $c\ d\ e\ f$ of a size sufficient to wrap round the drum is cut out. These lines, when viewed, through the slit, act as an infinite series of dots equidistant in each series, and exactly fulfil the requirements above indicated. Thus, if the convergent lines are so drawn that their intervals on $c\ e$ are such as to suit the maximum velocity V, and the intervals on $d\ f$, the minimum velocity v to be measured, then between $c\ e$ and $d\ f$ there will be position which will give stationary waves for every velocity between V and v. Moreover, equal distances along the drum correspond to equal differences of velocities ; thus, if V is 60 and v 20

* This equation may be put in the general form $v = \frac{60\ C\ t}{n}$ where C is a co-efficient depending on the series to which the wave belongs and on the particular number in that series. The table, page 4, gives the values of C for different waves.

rotations per minute, the positions corresponding to velocities of 50, 40, and 30 will be found by simply dividing *c d* into four equal parts, and by further subdivision the positions corresponding to all velocities between *V* and *v* can be obtained.

In the Cycloscope, as at present constructed, a box *a* (*Plate* III.), containing a reed, to the tongue of which a piece of very thin zinc, with a slit, has been soldered, moves in front of a drum, carrying a paper ruled with lines in the way described. The motion is given by the hand-wheel *b* to a pinion *c*, on the same axis, the pinion gearing into a rack attached to the slide *d*.

The reed box carries a small pointer *p*, which traverses a scale *s s*. The period of the reed is 60 complete vibrations per second. The ruled paper is prepared as follows :—Suppose that the perimeter of the drum is P, its available length L, and that the range of velocities which it is desired to measure is from 120 to 60 rotations per minute. A line of length P, is divided into $\frac{7200}{120}$ (= 60) equal parts. Then, if *h* (see *Fig.* 8, *Plate* II.) is the distance from *o* to the line corresponding to a velocity of 120—

$$\frac{h}{h - \mathrm{L}} = \frac{\frac{7200}{60}\mathrm{P}}{\frac{7200}{120}\mathrm{P}} = 2$$

whence $h = 2$ L. The point *o* on which the lines are to converge must, therefore, be taken at a distance 2 L from the divided line. The lines are now drawn sufficiently far to cover a breadth of paper equal to L, and in order that a rectangle equal to the development of the whole drum may be covered with lines, it will be necessary to produce the divided line and carry the divisions out further each way. White lines ruled with Chinese white, on a black or blue ground, and varnished after mounting with thin spirit varnish, have been found to answer very well. These lines should be about the same breadth as the slit. The paper so prepared is pasted on to the drum, and it is convenient, but not essential, to arrange it so that the centre line *o n* (*Fig.* 8, *Plate* II.) falls on the drum exactly opposite the junction, each line cut by the line *c d* will then be met by a similarly situated line cut by *e f*, and the junction will present the appearance shown in (*Fig.* 9, *Plate* II.)

The graduation of the scale should be performed *after* the mounting of the paper, in order that no error may arise from stretching of the latter. If a circle is traced round the drum at any of the intersections shown in *Fig.* 9, this circle will be divided into equal parts. Starting at any two intersecitons the lines are counted round and found to be *N* and *n* respectively, the speed required to produce the stationary double wave at these positions will be $\frac{2 \times 60 \times 60}{N}$ and $\frac{2 \times 60 \times 60}{n}$ respectively. The scale can, therefore, be marked at these two points, and the intermediate graduations can be obtained by subdivision.

A vernier could be employed in place of the pointer p, by which the primary divisions could be subdivided into 10 or 100 parts.

Referring to *Fig.* 9, it will be evident that only at the intersections, and at one intermediate point between each pair, will circles traced round the drum be divided into a whole number of equal parts. Circles traced at other positions will have one unequal division at the line of junction; this will cause a slight movement, or jump, of the wave at each rotation of the drum. This cannot, however, be mistaken for the steady progressive motion denoting that the position corresponding to the stationary curve has not been arrived at.

To make a reading it will now be necessary to start the reed and to move the hand-wheel b, until a stationary double wave is seen; the pointer will then indicate the speed.

To make the waves more visible, two small lenses e e are employed, fixed in the front and back of the reed box. The lens on the back of the box throws an image of the lines on the slit; that in front magnifies this image, and thus parallax is avoided. If the instrument is to be used in a dark situation, a small lantern is placed on the bracket t attached to the side of the reed box, in order to illuminate the portion of the drum under observation.

The reading can be made without taking the eye from the front lens, if a scale identical with that described is placed close in front of the drum, at such a height that its graduations can be seen through the slit, when the latter is set in vibration. It may be advantageous, in some cases, to place the ruled paper on a shaft, instead of attaching it to a drum driven by a belt and pulley; indeed, one of the great merits of the principle is that it can be thus *directly* applied to a machine, without the intervention of any mechanical transmission. In such a case it may be impossible to bring the apparatus close up to the shaft. If, however, the fork or reed vibrates in the focus of the object-glass of a small telescope, the observation can be made at a considerable distance from the shaft. The plan of placing the scale close up to the drum would then have to be employed, and it will be advisable to trace circles round the drum, each circle denoting the position corresponding to an integral number of rotations per minute. The slight error due to parallax would thus be obviated.

In the early experiments it was found difficult to keep up a sufficient supply of air to the reed without a considerable pumping power and large conducting tubes. By the utilization of the principle of the injector, or jet pump, this difficulty has been entirely removed. The air is supplied through a small flexible indiarubber tube from a pair of foot bellows. This tube terminates in a small glass tube drawn out to leave a narrow jet, $1\frac{1}{2}$ mm. in diameter. This fine jet is passed through a cork, fitted into a wide brass tube *k* (*Plate* III.) fixed into the lower part of the back of the reed box. The lower part of the brass tube is cut away to allow free access to the surrounding air. The arrangement is shown in enlarged section in *Fig*. 10, *Plate* II.

Air, of pressure about equal to a column of water 20 or 25 c.m. in height, is forced through the jet, and the reed vibrates perfectly, the mean pressure of air in the reed box being only about equal to a column of water $1\frac{1}{2}$ mm. in height.

In the original experiments it was necessary to devise a means for readily setting tuning forks in vibration. The arrangement shown in *Fig*. II. was found to answer remarkably well. A short piece of soft iron, with its ends turned up in opposite directions, is carried on an axis between the prongs of the fork, the latter being surrounded by a wooden box, to which the bearings of the axis are fixed. The bar forces the prongs apart, as shown in the figure, and when the axis is sharply turned through 90°, the fork is set in vibration.

It has so far been assumed that the period of a fork or reed is absolutely constant. This is not the case, as the fork varies slightly with temperature, vibrating more slowly as the metal becomes warmer. In some experiments made with tuning forks a loss ·011 per cent. per 1° Centigrade was observed. This would be too small to affect the value of the instrument for practical purposes, while, if it were employed for delicate investigations, a correction could readily be applied. Temperature similarly affects reeds, their period is also lengthened by an increase of pressure of the air by which they are set in vibration. By the employment of the air injector described in a foregoing paragraph, any considerable variation in the pressure of the air supplied is prevented. The mean of 22 fairly concordant observations gave ·010 per cent. for each degree Centigrade as the loss occasioned by rise of temperature. The determinations of the effect of temperature above alluded to were carried out by means of Lissajous' figures, and it may be mentioned that the latter can be produced by attaching pieces of paper with very fine slits to the forks, in place of mirrors as has been the usual practice hitherto. One fork is placed horizontally and the other vertically, a fixed lens being mounted between them, so as to form an image of one slit on the other. The great advantage of this plan is that with large forks the influence of the additional weight of the paper and attaching gum is inappreciable.

There are several methods of determining the absolute period of a reed or fork. These are described at some length in a paper communicated by Mr. A. J. Ellis, F.R.S., to the *Journal of the Society of Arts* for May 25th, 1877. The absolute period of a standard fork or reed being obtained, there is no difficulty in optically tuning any other number of forks or reeds to the same pitch.

The principle of the Cycloscope is now being employed in the construction of an apparatus for determining the absolute pitch of a fork or reed, and the experiments so far have given excellent results. If a steady rotary motion capable of perfect control is given to a drum carrying a ring of lines, and if the motion is so regulated that any recognised wave, given by a fork or reed of unknown period, is kept stationary during a measured interval of time, the exact number of rotations of the drum during this interval being accurately recorded, then evidently the period of the fork or reed can be obtained. It is not even necessary to attach a slit to the fork, as the edge of the latter is found to answer equally well.

Three determinations of the period of a 256 fork, made by Professor McLeod, gave the numbers 256·287, 256·281 and 256·287 vibrations per second; a 320 fork gave 320·364; a 384 fork 384·456, and a 512 fork 512·549. These numbers must be regarded as merely preliminary, as known imperfections exist in the apparatus.

The essential feature of the cycloscope is its extreme delicacy; this, while unfitting it for observations where it is required merely to read average speeds, renders it specially useful in cases when it is necessary to determine the absolute speed of a rotating body at a given instant.

For example, in Noble's chronoscope for measuring minute intervals of time, a number of discs are driven at a very high speed, and the breaking of electric circuits carried through the gun itself, or through screens in front of the muzzle, causes sparks to pass, and to mark the edges of the discs. If then the speed of the discs is known with certainty at the precise instant of firing, the distance between the marks on the discs gives a very accurate measure of the interval which has elapsed between the breaking of the circuits. All experiments with the Cycloscope tend to show that a constant rotary motion cannot be obtained, and that with the best machinery slight variations are occurring at every moment. In such a case as this it is particularly unsafe to trust to an average velocity, as it is quite possible that at the moment of firing, the actual velocity may differ very considerably from the average. If, however, to some portion of the machinery a wheel is attached, the circumference of which is accurately divided by a number of lines, then by observing these lines through a slit attached to a suitable fork or reed, it can be seen at a glance whether the machinery is running regularly. It will be necessary to apply some simple friction regulator which can be controlled by the observer; the *direction* in which the wave moves showing whether the speed is too high or too low for the stationary wave. Directly the wave has been brought to rest by the application of the break, the firing key which may be in charge of the same observer is put down.

Some interesting experiments have been made with discs on the principle of the thaumatrope, which in one direction at least promise results of practical utility.

If a disc provided with slits is driven at a constant speed by clockwork in front of another disc provided with a ring of dots or symbols, then, when the number of slits passing in front of the eye in a given time is equal to the number of dots which pass in the same time the latter will appear to be stationary.

Thus, if N and n are the number of rotations of the clock and machine discs per minute respectively, S the number of slits, d the number of dots.

When $NS = nd$; d dots will be visible and stationary. Thus S and N being given or assumed, d can be obtained for any assigned value of n.

If the machine disc is running a little too fast for the above equation, the dots will appear to move slowly in the *same* direction as this disc; if too slow, they will move in the *opposite* direction.

If $NS = 2\,dn$; $2\,d$ dots will be visible and stationary.

If in place of dots symbols alternately alike are employed thus—

/ \ / \ /

then, by reason of the superposition of adjacent symbols, when $S N = 2\ d\ n$ the appearance is $2\ d$ stationary,

X X X X X

where d is the *whole* number of symbols employed. Although the difficulty above alluded to, of obtaining a trustworthy standard rotary motion, places difficulties in the way of using this method for the *absolute* measurement of velocities, there is no reason against its adoption for the investigation of the *relative* speeds of two machines.

Thus, in the case of the twin engines so largely used on modern ships of war, by merely driving one disc from each engine a glance will show whether the two engines are running together, and if not, which is the faster. Moreover, by a suitable arrangement of symbols the same discs could be made to show whether the speeds of two such engines bear any simple ratios as 1: 2, 1: 3, 1: 4, etc., to each other. In the elucidation of the many difficult problems connected with steering this method promises to be useful.

Other applications of the principle of the Cycloscope might be adduced, but enough has been said to give some idea of its power and general adaptability.

To all cases where it is necessary to study carefully the working of a machine, the method can be applied with advantage, while its great elasticity permits it to be adapted to high or low speeds, long or short ranges of velocity, heavy engine machinery or light clockwork with equal facility.

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