R·E

PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS,

CONTRIBUTED BY

OFFICERS OF THE ROYAL ENGINEERS.

NEW SERIES.

VOL. XIX.

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PREFACE.

The publication of the present Volume has been delayed beyond the usual period, under the hope that much information of professional value, on subjects connected with the late war, would have been by this time received. With the exception, however, of the interesting account of the passage of a wet ditch at the siege of Strasburg, supplied by Colonel Lennox, the Editor has as yet been unable to procure any authentic details of Engineering operations, and it has, therefore, been thought desirable to issue the present Volume without further delay, and to publish another one as early as possible more especially composed of papers bearing on the war.

As it was under the Editorship of the late Lieutenant-General Sir W. T. Denison, K.C.B., that the Professional Papers were first published in the year 1837, the present seems a fit place to record the general regret experienced at the death of this distinguished officer, which occurred on the 19th January, 1871.

The Committee purpose to publish in connection with, but bound separately from, the next Volume (XX.), a complete index of all the papers that have been printed in any of the series up to the 20th volume inclusive.

The Committee also propose that the sense of the next Annual Meeting be taken upon the question raised at the last Annual Meeting, by Colonel Lennox, as to the discontinuance of the plan of publishing an annual Volume, and of in lieu thereof, printing and distributing Papers as soon as possible after their receipt.

C. S. HUTCHINSON,
Lieut.-Colonel, Royal Engineers,
Editor.

Railway Department,
Board of Trade, Whitehall,
March, 1871.

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PROFESSIONAL PAPERS.

PAPER I.

DESCRIPTION OF A LANDING STAGE ERECTED AT DRAKE'S ISLAND FOR HOISTING HEAVY GUNS.

BY LIEUTENANT H. DENISON, R.E.

As the old lift on the north side of Drake's Island, in Plymouth Sound, was deemed unsafe for hoisting guns of as large a calibre as 9 ins., a landing stage was designed and erected by Lieut. Hare, R.E., on the north-east side of the island.

The total height from the beach to the level of the platforms in the casemates is about 48 ft., and the rise of the tide is 18 ft. at high-water spring tides. The beach is very rocky, and, consequently, a passage had to be made by blasting, so that the lighter in which the guns were conveyed from the gun-wharf might ground in the sand at the end of the pier.

The stage is made entirely of red pine, and consists of two ways, 6 ft. apart, supported on trestles and struts, which again are guarded from side strains by additional struts. At the end of the stage is a small sort of mole, upon which is constructed a level platform capable of receiving four or five 12-ton guns at a time. The height of this platform is exactly the same height as the baulks fixed on the deck of the lighter when grounded at the end of the pier.

There were originally two footways between the ways, but one was removed in order to allow room for the revolution of the trunnions of the gun when parbuckled up the incline. The outside of the mole is made of rough rubble masonry laid in Roman cement, half sand; and the interior consists of a sort of coarse concrete made out of the dunstone gathered from the beach. The time taken in erecting the stage was three weeks; and the entire cost was £167. The diagrams explain for themselves the method of construction. Mooring chains were afterwards added to guard against the force of the sea during the equinoctial gales, but their services have never been required.

The following are the calculations which were made to ensure the stage being sufficiently strong :—

1st. To find at what intervals the struts and trestles supporting the ways should be placed: Assuming the trunnion of the 25-ton gun to be 1 ft. in diameter, the greatest weight which can come upon one of the ways is when the trunnion of the gun touches it as shewn in the section of the trestle, since the centre of gravity of the gun lies nearly in the axis of the trunnions.

This weight will be about $\frac{5}{6} \times 25$ tons, since the ways are at 6 ft. central intervals, $= 46666$ lbs.

Disregarding the slope of the ways, the case will be simply that of a beam supported at both ends and loaded in the middle;

$$\text{then } \frac{W\,x}{2} = \frac{f\,I}{y_o}$$

$$\begin{aligned} \text{where } W &= \text{total weight} = 46666 \text{ lbs.} \\ x &= \text{length in inches} \\ f &= \text{coefficient} = 9540 \\ \frac{I}{y_o} &= \tfrac{1}{6}\, bd^2 = \frac{14'' \times 14'' \times 14''}{6} \end{aligned}$$

$$\text{factor of safety} = 4$$

The dimensions of the ways were assumed 14 in. by 14 in., being the biggest timber easily procured. Then

$$x = \frac{2 \times 9540 \times 14 \times 14 \times 14}{4 \times 6 \times 46666} \text{ inches}$$

$$= 46\tfrac{1}{2}'' = 3'\ 10\tfrac{1}{2}''$$

The actual distance between the centres of the points of support is about 4 ft. 6 in., but as a factor of safety of 4 has been taken, they will be amply strong enough.

The only other points requiring calculation are, the depth of the struts *s s* and the thickness of the uprights of the trestles to resist buckling.

The struts are inclined to the vertical at 35°, the maximum thrust down each would be therefore

$$\frac{W}{2} \cos 35^\circ = \frac{46666}{2} \times \cdot 81 \text{ lbs.} = 18900 \text{ lbs.}$$

As the sectional area of these struts is 72 square inches, and 1,000 lbs. per square inch may be safely put upon deal without fear of crushing or loosening the joints, they are amply strong enough.

Next to find the depth of the vertical timbers to resist buckling. The longest one is about 17 ft. 6 in. The formula is

$$\frac{p}{s} = \frac{f}{1 + \dfrac{l^2}{cr^2}}$$

$$\begin{aligned} \text{where } P &= \text{breaking load} = 46666 \text{ lbs.} \\ s &= \text{sectional area} = ld = 12d' \end{aligned}$$

$$f_w = 7200$$
$$l = 17 \cdot 5 \times 12 \text{ inches}$$
$$c = 3000$$
$$r^2 = \frac{h^2}{12} \text{ here } h = 12$$
$$= 12$$

Assuming one dimension 12″ and factor of safety 4

$$\frac{46666}{12 \times d} = \frac{1}{4} \times \frac{7200}{1 + \frac{17 \cdot 5 \times 12 \times 17 \cdot 5 \times 12}{3000 \times 12}}$$

$$\text{or } d = \frac{46666 \times 2 \cdot 225}{12 \times 1800}$$

$$= 6 \text{ inches nearly.}$$

As the timbers are 12 in. by 12 in. they are amply strong enough.

The lighter in which the guns were conveyed from the gun wharf, is shewn in plan and section; as also the additional timbering used for the support of the guns.

Three or four 12-ton guns were brought over at a time at high water, and the lighter was allowed to ground at the end of the pier, so that the timber upon which the guns rested had a slight inclination towards the pier, as shewn in the sketch.

A 6-in. preventer rope was passed round the gun through a leading block on the deck of the lighter to a capstan. This rope was then eased off gently, and the gun heaved forward by handspikes until it rolled on to the pier. As soon as the gun arrived on the ways, the preventer rope was cast off, two parbuckling 6-in. ropes were passed round the gun, one just above and the other below the trunnions; a third 6-in. rope was also fastened to the pry-pole of a gyn which was placed in the bore for the purpose of hauling the muzzle forward as the breech gained ground. In order to make the gun rotate upon a nearly horizontal axis, 12 in. by 12 in. skids were lashed on to one side of the ways, as shown in the section. The three ropes were worked on three winches placed at the top of the incline and fastened by ropes to two large spars laid across the interior of the casemate. When the fall had to be shifted, the winches were eased off, one by one, until the gun was kept from slipping back by two "scotches" of the form shown in the figure. These scotches were worked by two men who advanced up the incline with the gun. The time taken in getting one gun up the incline was 45 minutes, and three guns were disembarked and hoisted in one morning. The carriages and slides had been previously hoisted up the slip, and arranged in the casemates. The guns were brought into the casemates on rollers.

H. D.

PAPER II.

DESCRIPTION OF A CONCRETE BRIDGE CONSTRUCTED OVER THE METROPOLITAN DISTRICT RAILWAY.

COMMUNICATED BY THE EDITOR.*

The tests applied to the experimental bridge of concrete, set in cement, erected over that branch of the Metropolitan District Railway which forms one of the junctions between the Inner Circle and the West London Extension, prove conclusively the reliable character of concrete exposed to compressive strains. The structure experimented upon spans the open cutting between Gloucester Road Station and Earls Court Road. It is a flat arch of 75 ft. span, and 7 ft. 6 in. rise in the centre, where the concrete is 3 ft. 6 in. in thickness, increasing towards the haunches which abut upon concrete skewbacks. The concrete of which the bridge is made is composed of screened gravel and Hilton's Portland cement, mixed in the proportions of about seven to one, carefully laid in mass upon close boarding set upon the centering, and enclosed at the sides.

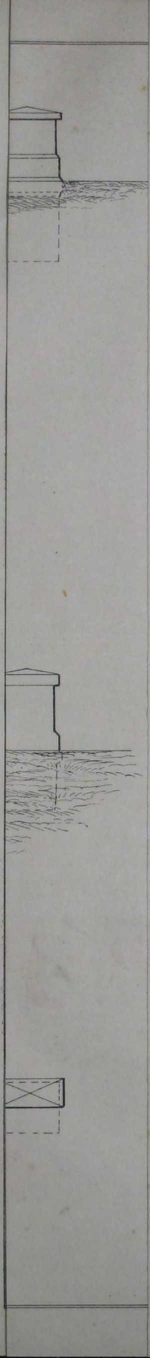
The concrete was mixed by hand labour, as many men being employed to mix and wheel into place as there was room for.

The bridge was formed in three portions; the centre portion, 12 ft. wide, being first made and tested. Each portion was formed in one operation.

The amount of concrete employed in the centre portion was about 4,800 cubic feet, which weighing $1\frac{1}{4}$ cwt. per cubic foot, gave a gross weight of 300 tons for the structure alone. The centre of gravity in the half-span being 16 ft. 6 in. from the abutment—the weight of the same, 150 tons, and the rise of the arch, 7 ft. 6 in.—the thrust at the crown is equal to 330 tons.

The arch being 3 ft. 6 in. deep in the centre, and 12 ft. wide, a sectional area of 42 square feet, is available to resist the thrust, which is, consequently, equal to 7 tons 17 cwt. per square foot. The additional strain imposed upon the concrete in the arch for every ton per foot run of distributed load is equal to $2\frac{1}{4}$ tons per square foot, and the maximum strain for a rolling load of 1 ton per foot run is about $3\frac{1}{4}$ tons per square foot. It occurs when the load covers about five-eighths of the span.

* The Editor is indebted to T. Marr Johnson, Esq., Engineer of the Metropolitan District Railway, for the description and drawings of this concrete bridge.



In testing the centre portion of the bridge, rails were laid upon sleepers over the arch, which brought a load of $\frac{2}{75}$ of a ton per foot run upon the structure. Seven trucks, weighing together with their loads 49 tons, were formed into a train, having a wheel base of 57 feet; hence the rolling load amounted to $\frac{49}{57}$ of a ton per foot run. The deflection produced by the passage to and fro of this train four times was noted with a spirit-level upon a standard cemented to the sides of the arch at a distance of one-third the span from the abutments. When one side of the bridge was loaded, the extreme rise of the haunch on the opposite side was about $\frac{1}{16}$ of an inch, which was produced by a maximum strain of 10 tons 14 cwt. per square foot.

At a subsequent trial, a mass of gravel 10 ft. wide, 3 ft. thick at the crown, and 6 ft. deep at the haunches, was laid over the bridge, and upon this ballast was placed the permanent way. After an interval of a few days, the trucks, loaded as before, were passed over the bridge, at first in pairs, and finally all together.

In this test the strain upon the concrete was as follows:—

	Tons.	cwt.
The weight of the arch as before	7	17
170 Tons of ballast	4	8
Strain per square foot from dead load	12	5
Strain per square foot from passing load	2	17
Total strain per foot	15	2

After repeated transit the load was left upon the bridge all night, and the arch upon examination, showed no signs of failure or distress under the severe strains to which it had been exposed.

That a very small stress was developed upon the underside of the arch was evidenced from the fact that none of the comparatively loose pebbles on the inner surface of the arch became detached; the interior of the structure was much denser than the outside and at 6 inches from the outer surface was excessively hard.

The exterior of the work was rendered in Portland cement to resemble Ashlar.

Some fine cracks appeared in the spring, attributed to the further shrinkage of the concrete by drying, but these have not extended.*

* The porous nature of even such good concrete as that used in this bridge is shown by the fact of rain passing through it in the course of a few hours.

PAPER III.

REPORT OF THE DEMOLITION OF THE SHIP "LEICHARDT."

BY LIEUT. JEKYLL, R.E.

The "Leichardt," a full-rigged ship of over 700 tons burden, was run down while lying at anchor at the Nore, by a steamer named the "North Star," in November, 1868.

The ship was outward bound for New Zealand. She went down on the tail of the Nore Spit, about a mile to the eastward of the light-ship, where the depth of the water is $4\frac{1}{2}$ fathoms at low water spring tides. She lay on an even keel, and shortly after sinking assumed a position up and down stream, with her head to the ebb tide. Soon after she foundered, endeavours were made to save the cargo, and with this object divers were employed for nearly three months, but they recovered nothing but an anchor and cable, two coils of rope, and three casks of provisions; they ascertained, however, that the wreck was clear all round, and that no obstruction such as cordage or debris existed to impede the operations of the divers; before they left they attached buoys to the bow and stern, which shewed at three-quarters ebb.

The nature of the bottom is hard mud covered with a thin layer of sand; as usual in the case of an obstruction in a strong tideway, a trench was washed all round her, the depth of which varied from 12 to 18 feet. The masts of the ship, which, together with the bowsprit, remained standing for some months, were carried away by passing ships in the course of the winter, and the wreck itself was frequently fouled in the same manner, notwithstanding the precautions of the Trinity Board, by whom a wreck-buoy was laid close to the ship, and a cutter of 34 tons, moored alongside, to shew a light at night. On the 23rd April, a large ship, called the "Lord Raglan," came into collision with the wreck and carried away the starboard quarter, a good deal of timber floating to the surface.

By this time, however, the wreck had sunk a considerable distance into the mud, so much so, that there was never less than two fathoms of water over her deck, and consequently she did not cause so much annoyance to the navigation as she had done during the winter months, when her deck was barely covered at low water.

As it was known that the value of some portions of the cargo was considerable, she had been purchased by Mr. Henry Sykes, a civil engineer, by whom the divers just referred to were employed. He, finding the process of recovery adopted to be unremunerative, applied in May, 1869, to the Director of the Royal Engineer Establishment to have her blown up, thinking apparently that by this means some of the cargo or timber of the ship might be saved. I accordingly received instructions to examine and report upon the condition of the wreck, and to send in a project for demolition, with an estimate of the expense. On the 10th of May I proceeded to the Nore, made an examination, and obtained particulars from the Master of the Trinity tender, the substance of which is detailed above, and next day sent in a report and project in which I recommended that gun-cotton should be employed in charges of 90 lbs., to be exploded by means of detonating fuzes, and stated my opinion that 800 lbs. would be required to complete the demolition, and that the total cost would not be less than £175. Mr. Sykes was at once made acquainted with these particulars, and was requested to supply the gun-cotton, and in the meantime a design for sheet iron cases, suitable to the proposed charges, was prepared.

The estimate of £175, did not, however, meet the approval of Mr. Sykes, who thereupon, declined to avail himself of our services. The negotiations then dropped, but were renewed towards the end of July, by the Trinity Board, to whom Mr. Sykes had surrendered his right to the vessel, and who now requested that immediate steps might be taken to effect the removal of the obstruction.

The plan as originally proposed was finally adhered to, and the same estimate sent in. The iron cases were ordered to be made in conformity with the design (Fig. 1) by Messrs. Spencelayh and Archer, of Rochester, and the 800 lbs. of gun-cotton were ordered from Messrs. Prentice, of Stowmarket. The iron cases differed in construction to any that have hitherto been made, and as they were found to answer extremely well, a description is here given. The thickness of iron was $\frac{1}{8}$ inch, which for the curved portion was sufficiently strong to resist the pressure of 50 feet of water, but the flat ends required some sort of strengthening, for which purpose three standards of $\frac{1}{2}$-inch iron rod were introduced, abutting on a $\frac{1}{2}$-inch plate at the bottom, and a ring of the same thickness at the top. By this means the pressure of the water on the top and bottom was transferred to the rods, which were placed at such intervals as not to interfere with the packing of the 7-inch discs of gun-cotton. The tops and bottoms were made of the best charcoal iron, and a flange of an inch in width was turned down all round the edge. The diameters of the tops and bottoms were made $\frac{1}{8}$ inch larger than that of the body into which they fitted, and the latter was heated and shrunk on, and lastly riveted. An aperture, 8 inches in diameter was left in the top, and was closed by a flat plate of $\frac{1}{2}$-inch iron, secured by nuts and bolts, the joints being rendered water-tight with an India-rubber ring and red lead.

The cases were of two sizes, viz., 2 ft. and 1 ft. 4 in. in length, the same diameter, 1 ft. 4 in., being preserved in each case, and they were calculated to contain respectively 90 lbs. or 60 lbs. of compressed gun-cotton; six cases of the large size and four of the small were manufactured, and their aggregate cost was £38 10s. complete. The cases were all tested by being submerged for 24 hours, when empty, in 6 fathoms of water, and they all remained dry. They were all delivered by the manufacturers during the second week in August, by which time also the first instalment of gun-cotton, amounting to 484 lbs., was received from Messrs. Prentice.

The plan of operations now decided upon was to fire the whole number of charges in two series of five each; one series extending along the entire length of each side of the ship. The five charges, consisting of three large and two small, were, therefore, loaded, and wires of the proper lengths to correspond with the intervals of the charges were sealed into the tops, which were subsequently screwed down. The cable used was Gray's wire coated, and by adopting the plan just mentioned, all joints were done away with. Two detonating fuzes were inserted in each charge, thus making 10 to be fired in continuous circuit. The earth was made by soldering the wire from the last fuze to the inside of the top of the extreme charge.

The wreck was visited on the 17th August, and a staple was driven by the diver into the stem, to which a buoy was attached. It was endeavoured to commence active operations the next day, but bad weather interfered, and on reaching the spot we were unable to work, but left the charges on board the smack.

On the 20th, however, the weather was favourable; the Nore was reached at 3.30 p.m., and in the course of an hour the buoys began to show. The launch steamed out and dropped her anchor 50 yards above the bow of the ship, and then dropped down the stream until she took up a position clear of the wreck and a little to the north of the bow; the cable was then belayed and two more anchors were laid out, one from the stern and the other from the starboard bow; with these three holdfasts the launch maintained a perfectly steady position. (See Fig. 2.)

The diver now went down by the rope which he had made fast on the last occasion to a staple driven into the stem of the ship, and which led him direct to that spot; his instructions were to examine the staple, and if possible render it more secure by driving it in a little further. He did not succeed in accomplishing this, but found a better point of attachment in the shape of a chain cable, partially imbedded in the sand, and close against the ship's bow; he then came up having been under water $9\frac{1}{2}$ minutes.

Meanwhile, two other operations were going on, conducted partly by our own men and partly by those employed by the Trinity Board. A weight of 1 cwt. was sunk a few yards south of the ship's stern; to this weight a long piece of $1\frac{1}{2}$-inch rope was attached, and paid out round the stern, and up to the position of the launch, the bight being kept swung out of the way by the tide. (See Fig. 3.)

The five charges were placed in a row-boat, and brought out to the launch, the drum remaining on board the tender, and the electric cable being paid out from it. A tail block was attached to the line charge, and a buoy fastened with spunyarn to each of the charges; these were then placed in the water in succession and swung out into a straight line by the tide. A dingy held on to the line charge, and rove the 1½-inch rope, already mentioned, through the tail block, the other end of the rope being held tight by the sunken weight. These operations were complete by the time the diver came up. (See Figs. 4 and 5.) The latter now went down again, taking with him a metal block, to which a pair of clip hooks were attached, and through which a rope was rove. He hooked the block into a link of the chain cable mentioned above, and immediately signalled to this effect on the rope. The earth charge was bent on to one end of the rope, and its buoy having been cut off, it was hauled down by pulling on the other end; by this means the earth charge was sent down direct to the diver, who at once unbent the rope, unhooked the block, which was hauled to the surface, and fastened the charge in its place. He then came up, having been 16 minutes in the water. (See Fig. 6.)

The position of affairs at this time was as follows, (see Fig. 7):—Charge I securely fastened to chain, and in contact with the ship's stern; charge II with its buoy cut off, a few feet under water; charges III, IV, and V, floating in a line with buoys attached; the electric cable, connecting charge V with the tender, and a rope from the weight at the bottom, passing through the single block on charge V and held in a dingy.

The next thing to be done was to bring the whole line of charges in contact with the ship's bottom. For this purpose, the dingy containing the running fall of the 1½-inch rope, rowed to the tender; the fall was then passed on to the deck, and manned, preparatory to hauling. The buoys on charges III, IV, and V, were simultaneously cut off, a small line was attached to charge V, and the men commenced hauling on the rope, continuing until stopped by charge V jamming against the vessel's starboard quarter. The small line was held at the surface, and buoyed to indicate the position of charge V. (See Fig. 8.)

To avoid the possibility of doubt, as to the situation of the charges, the moorings of the launch were shifted and again laid out, so as to bring her close to the stern of the vessel, and the diver went down, using the small line to guide him to charge V. He was provided with a large staple and a hammer, and finding the charges correctly placed, secured charge V, by driving the staple into the ship's bottom. It took six minutes to accomplish this. As the two extreme charges, I and V, were known to be correctly situated, there could be no doubt, that the intermediate charges were also in a proper position, otherwise the length of the line of charges would not have corresponded with the length of the ship.

The anchors of the launch were weighed, and she steamed to the tender, moored at a distance of 100 yards from the wreck. The friction machine was taken out and proved, connection was made, and the five charges exploded simultaneously.

The effect of the explosion was as follows:—First, a sharp sudden concussion, indicated on the surface by a sort of shiver, and innumerable little jets of water about a yard high; this was instantly followed by the rise of a huge bank of broken water extending the whole length of the ship, and about 30 feet in height; as soon as this subsided, masses of black mud and discoloured water came up from the bottom, bringing up broken spars and timbers, with which the surface soon became thickly strewn. Among the debris were hundreds of corks, bearing the brand of Cope and Co., the appearance of which was evidently due to a large consignment of bottled stout, known to be in the hold; there were also numbers of candles floating about; some of these were captured and found to burn remarkably well in spite of ten months' submersion. The timber consisted chiefly of deck planks and other articles of pine or fir wood; the ship being built of oak and teak, none of the principal timbers floated, as both of these descriptions of wood become quickly water-logged. A number of fish were killed, consisting chiefly of eels, whiting, and cod, besides small fry, these floated to the surface, and were caught by the boatmen, numbers of whom had congregated on the spot. The timber was also secured by them, but its value cannot have been great. As soon as the electric cable was hauled in the party returned to Chatham, which was reached at 9.30 p.m.

An examination by sounding with the lead was made next day by the Master of the Trinity tender, from which it appeared that very considerable damage had been inflicted on the wreck, and that a quantity of broken and detached timber lay all round her.

I was afterwards informed that during the three days succeeding the explosion, a great quantity of timber was washed ashore at Sheerness, Southend and the Isle of Grain.

We were unable at this time to pursue our operations further for want of gun-cotton, Messrs. Prentice having failed to send the remainder in proper time, a fortnight was, therefore, allowed to elapse before anything more was done. In the mean time the spring tides had been running, and the effect of the strong current had made itself very apparent upon the now shattered wreck, so much so, that it was all level with the sand, with the exception of the stern.

On the 3rd Sept. we again made an expedition in the steam launch to the Nore, taking one 90 lbs. charge only, which was loaded with the gun-cotton that happened to be in store, the second instalment not having yet made its appearance though nearly a month overdue.

The same precautions were adopted that have been described above to keep the launch in a steady position, and the charge was placed by the diver in contact with the stern-post and securely lashed. It was exploded by the frictional machine and produced a great effect.

Soundings, taken immediately afterwards, showed that in no place did any portion of the wreck stand more than 3 feet above the sand, the depth of water being $4\frac{1}{2}$ fathoms.

Thereupon a communication was addressed to the Trinity Board, informing them of the state of affairs, and asking if they were satisfied with the extent of the demolition. Up to the present time no answer has been received.

H. J.

BLOWING UP OF "LEICHARDT."

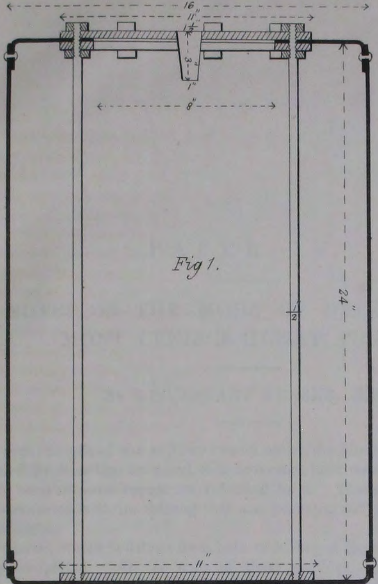


Fig 1.

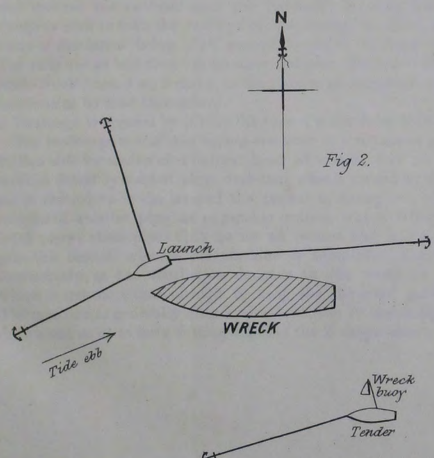
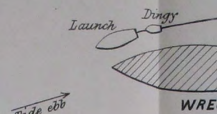


Fig 2.



Fig

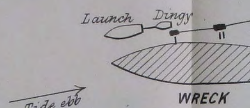
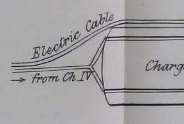
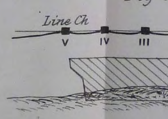


Fig 4.



Fig

Fig 6



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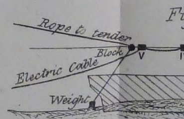

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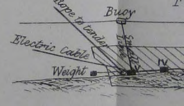


PAPER IV.

NOTES ON THE MODE OF DRIVING THE MONT CENIS RAILWAY TUNNEL.

BY LIEUTENANT FRASER, R.E.

The great length of the railway tunnel under the Mont Cenis, as well as the unusual difficulties that have had to be overcome, have made it so celebrated that there is need of some excuse for referring to it. There are, however, some points connected with its driving that are, perhaps, not generally known, and may be useful.

The tunnel, which is driven from both ends, has a large portion on each side already completed. At the ends of these portions, advanced galleries are pushed forward; the latter are about 2½ metres square. (See Fig. 1.)

In the completed parts the traffic runs on a double line of rails; while in the advanced gallery (Fig. 2) the following lines are laid down, and keep pace with it, viz., two very narrow gauge lines, *ab*, *cd*, along which small trucks travel and remove the rubbish from the forehead; between these, a line of broader gauge is laid, to take the carriage of the boring machine, the projecting portions of the latter being high enough to allow the trucks to pass under them. The rails are so laid that the distance between the inner ones of each of the small truck lines, viz., *b* and *c*, is the same as in the completed tunnel, and they continue to be used throughout.

Drainage is secured by giving the tunnel a rise from both ends to the centre.

The motive-power of the boring-machine is compressed air, produced at the Italian side by means of a natural head of water; and at Modane by pumps, worked direct by a set of large over-shot wheels turned by the river. Here the air is carried up to the level of the tunnel in strong iron pipes placed on short lengths of smaller pipe as expansion rollers, which latter are supported on brick piers; these pipes then go up an incline and into a storehouse just outside the tunnel, whence the machine is supplied. The air is not worked expansively, as the ventilation depends on the waste air from the machine, which is not more than enough to keep the advanced gallery cool and pure. The machine is generally armed with from 8 to 10 borers, the bars of which are drawn out so as to have cutting edges of the Z shape shewn in Fig. 3. These borers have a motion of rotation, as well as a forward motion, and they can be inclined to a certain extent so as to allow of the holes being angled as required. Above each is a small pipe which squirts water into the hole and helps to clear it and keep down dust.

The men work in three reliefs, averaging about 8 hours each; about 40 of them work at a time with the machine, which takes from 5 to 15 hours to bore the necessary holes; generally, about 62 of these are enough, though sometimes as many as 80 are used; their depth is from 1 to 1·4 metres, and they are generally arranged as follows: a large central hole, about 10 centi-metres in diameter, is first made; the other holes, each about 3 centi-metres in diameter, are roughly arranged round the central one, in three concentric rings; the outer ring is driven close to the edges of the gallery, and the holes are angled, (see longitudinal section) so as to bring away as much as possible of the rock. When the boring is done, the machine is drawn back about 15 metres, and is protected by moveable doors. The central hole is not charged at all; the inner ring of holes is first loaded, and all its holes fired as simultaneously as possible with Bickford's fuze, or the "Mêche de sureté." The discharge breaks away a cone out of the face, the large central hole causing the rock to yield more easily. The other belts are fired in succession, each blowing in more of the rock towards the centre.

The effect of the firing of each belt is roughly shown by the chain-dotted lines on the longitudinal section.

Those holes which fail have to be untamped and re-charged. It seldom happens (perhaps once or twice a year) that the machine has to be brought up again to act on the work it has already done The progress of the advanced gallery is said to be only from 7 to 10 per cent. less than the depth of the holes.

It is stated that roughly speaking, 440 lbs. of powder are used each day in the two tunnels. Assuming that in each advanced gallery 140 holes per day are fired, of an average length of 1·2 metres, and of a diameter of 3 centi-metres, the 280 holes would together hold, when full, about 482 lbs. of powder; so they must be nearly quite filled with powder when charged, as it appears that very little of the 440 lbs. is used except in the machine-made holes. Firing by electricity has been tried and rejected, because it was thought that tamping would be dangerous, except with copper wire, and this makes it too expensive. Gun cotton also had a trial, but was not liked, as its action was so violent that it did much damage in the gallery, very likely by the effects of an after explosion, such as gun cotton is known to be liable to; it also poisoned the workmen, so that in the language of the engineer who described it, "they fell like flies."

The advance of the gallery is very variable, as veins and bands of quartz are constantly met with in the mica-schist, which is not itself very hard. Under favourable circumstances, each advanced gallery progresses almost 2 metres in 24 hours on the average.

I am indebted to the kindness of Mons. Sommeilier, the directing engineer at Turin, for the following table, complete up to the end of September, 1869, which gives an exact history of the progress of the work. It will be seen from it, that after the machinery was fairly started, it shewed itself superior to hand labour, and that increased experience caused an improvement each year in the annual progress; this is very marked up to 1867, particularly as it is to be remembered that each year the further advance of the headings increases the difficulty of working. In the present year very good progress has been made; thus at Bardonnêche, the average for each day of March was over $8\frac{1}{2}$ feet, an extraordinary rate, considering that the heading had advanced nearly $3\frac{1}{2}$ miles into the mountain, and that the rock is Mica slate, with constant beds and veins of quartz in it. From external observations, it was feared at an earlier stage, that there was a thick bed of quartz rock, which, from the direction of its dip, was likely to cross the tunnel; but happily this has not proved to be the case, and it may reasonably be expected that the headings will meet in another 18 months, after which the tunnel can be widened with ease to the full size, and the railway communication will be complete from Calais to Naples.

It is rumoured that after the Mediterranean line, as it is called, is completed, the French government may buy up the Fell railway, to be kept in working order as a military line. It would form an admirable supplement to the other, and would very likely be the only one along which a passage could be forced in the face of an army on the Italian side, as, probably, a small force in possession of the Bardonnêche end of the tunnel could prevent all egress, and it seems almost impossible that an advanced guard could be passed over the mountains to dislodge them, as Bardonnêche is among the spurs of the Alps, many miles from the line of the Mont Cenis pass, and is, in this respect, much more secure than the end at Modane.

17th Sept, 1869. T. F.

MONT CENIS RAILWAY TUNNEL.

Detail of the Monthly progress in Metres, made in each Tunnel during the years 1868 and 1869.

Years.	Progress Made. Bardonnêche. Monthly.	Quarterly.	Total.	Modane. Monthly.	Quarterly.	Total.
Progress to 1st Jan., 1868	„	„	4724·50	„	„	3122·15
	Metres.	Metres.		Metres.	Metres.	
1868 Jan.	54·30			51·90		
Feb.	49·00	152·60		47·05	159·80	
March	49·30			60·85		
April	46·90			62·45		
May	61·30	168·00		54·50	171·10	
June	59·80			54·15		
July	63·90		638·60	64·80		681·55
Aug.	52·10	166·00		56·80	178·45	
Sept.	50·00			56·85		
Oct.	52·20			63·25		
Nov.	56·10	152·00		61·85	172·20	
Dec.	43·70			47·10		
1869 Jan.	50·90			56·45		
Feb.	60·60	193·40		51·75	162·25	
March	81·90			54·05		
April	76·75			48·25		
May	71·90	219·20		53·70	147·25	
June	70·55			45·30		
July	69·10		622·90	50·90		476·80
Aug.	68·40	210·30		58·25	167·30	
Sept.	72·80			58·15		
Oct.						
Nov.						
Dec.						
Total progress made to 1st of October, 1869.			5986·00 metres.			4280·50 metres.

Table of the progress, in Metres, made at each end by ordinary and by mechanical means, up to the 1st of October, 1869.

Description of Work.	Entrances of Bardonnêche. Years.	Progress in Metres.	Total.	Modane. Years.	Progress in Metres.	Total.	Total of the two Entrances. Work done in each Year.	General Total.
Ordinary Manual Labour.	1857	27·28		1857	10·80		38·80	
	1858	257·57	725·00	1858	201·95		459·52	
	1859	236·35		1859	132·75		369·10	
	1860	203·80		1860	139·50	921·00	343·30	1646·00
				1861	193·00		193·00	
				1862	243·00		243·00	
Work with Mechanical Appliances.	1861	170·00					170·00	
	1862	380·00					380·00	
	1863	426·00		1863	376·00		802·00	
	1864	621·20		1864	466·65		1087·85	
	1865	765·30	5261·00	1865	458·40		1223·70	8620·50
	1866	812·70		1866	212·29	3359·50	1024·99	
	1867	824·30		1867	687·81		1512·11	
	1868	638·60		1868	681·55		1320·15	
	1869	622·90		1869	476·80		1099·70	
Total progress made to 1st October, 1869			5986·00 metres.			4280·5 metres.		10266·50 metres.

	Metres.
Total length of Tunnel	12220·00
Length completed to 1st October, 1869..............	10266·50
Length not completed	1953·50

MONT CENIS TUNNEL.

FIG 1.
ELEVATION OF FOREHEAD.

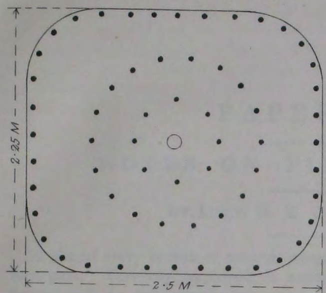
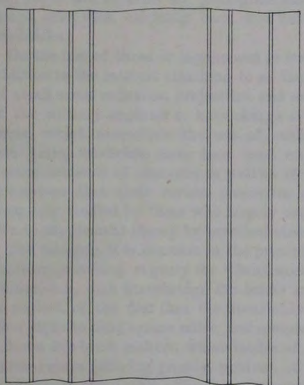
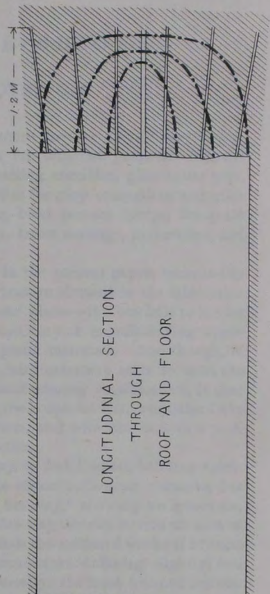


FIG 2.
PLAN





CUTTING EDGE
OF BORER.

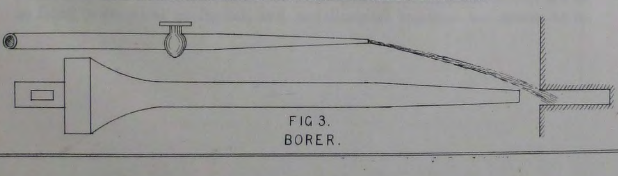


FIG 3.
BORER.

PAPER V.

NOTES ON FIRE-BRICKS.

BY LIEUT. G. E. GROVER, R.E.

In almost every branch of modern manufacture fire-clay plays a very important part. Variously employed, it assumes for different purposes different forms; such as, for example, gas retorts, smelting crucibles, glass-house pots, seggars for baking porcelain and pottery, muffles for glass enamelling and gilding, sieges and cuvettes for plate-glass fusing, blast furnace tymps, fire-grate lumps, oven tiles, calcining bars, flue linings, boiler seatings, pyrometers, and fire-bricks.

On the last of these it is proposed to treat in the present paper, because—in addition to the interest attaching to so important an element in the fabrication of small arms, ordnance, projectiles, and armour plates—it often falls to the lot of the military engineer to have charge of machinery or manufacturing appliances, which necessitate the use of such special materials. And though, of late years, fire-bricks have been used on a very extensive scale to meet the several demands of domestic as well as of manufacturing requirements, it does not appear that their various properties or their special characteristics have been duly studied by those who largely use them, and who are thus in a position to supplement theory by practical observation.

For instance, it is common in the present day to find English building specifications providing vaguely for "brickwork to steam boilers, air furnaces, flue linings, &c., with Stourbridge fire-bricks and fire-clay," shewing an ignorance, or neglect, of the fact that the Stourbridge fire-clay district covers an area of from eight to nine square miles, and comprehends the scattered works of at least a dozen fire-brick makers, whose modes of manufacture differing slightly, and natural clays differing greatly, produce, of necessity, the most unequal results. And, again, there may often be seen among the newspaper advertisements of the day, invitations in general terms for tenders to supply "Stourbridge, Welsh, and Windsor fire-bricks, fire-clay, loam, and sand, according to sample" —such a condition being, of course, too inexplicit to be of any real value. Yet, though, the general knowledge of this technical subject appears to be somewhat inexact, the most valuable contributions to it have been made from time to time by such eminent authorities as Messrs. Abel, Siemens, and Rankine, Drs. Percy, Richardson, and others; and frequent allusions to it are to be found in chemical, geological, and metallurgical treatises too numerous to here catalogue.* However, the subject does not appear to have hitherto received, at manufacturers' or metallurgists' hands, the careful attention which it certainly deserves. The choice of refractory building materials is usually determined (as is very natural) by local considerations, and there is not thrown upon the question that light which might, according to reasonable expectation, be derived from a series of comparisons by practical men of actual tests under similar conditions.

The intended object of the following remarks is as much to elicit, as to impart, information. For it is conceived that the only true method of advancing knowledge in this particular branch of manufacture is to take stock, so to speak, of what has been already determined exactly or accepted indisputably, and thence to proceed—as from a starting point—to careful investigation and deduction. With this view, it is proposed to compile briefly the recognized theories of reliable inquirers into the subject, and to combine therewith the practical experience as to the production and use of fire-bricks, derived from visits paid by the writer to some of the most noteworthy manufacturing establishments in the country, and from the employment of many distinct kinds of fire-bricks and fire-clays in the furnaces, cupolas, gas retort benches, and boiler flues, of the Royal Arsenal, and other stations in the Manufacturing District.

Fire-bricks are so named from their property of comparative infusibility when exposed to very high temperatures. I say *comparative*, because no known material seems to enjoy absolute immunity from decomposition under the attacks of unlimitedly intense heat. Even the nominally infusible substances —pure silica, alumina, lime, and magnesia—the natural varieties of rottenstone (a very aluminous silicate of alumina, decomposed from rock), and the silicates of magnesia—talc, asbestos, and steatite or soapstone—have been known to succumb in the flame of an oxy-hydrogen blowpipe or between the poles of a galvanic battery.

It is, however, clearly unnecessary to discuss in this paper any materials but those practically obtainable in large quantities; and of these the chief components, in Great Britain, are the so-called fire-*clays*, with the exception of the siliceous Dinas *rock* in the Vale of Neath, Glamorganshire, to which fuller reference will be made hereafter.

Clays proper are chemical compounds, occurring under different phases in numerous geological formations, and consisting of hydrated silicates of alumina, either alone or in combination with silicates of potash, soda, lime, magnesia, iron, manganese, &c. Though a sediment from water (being, in fact, decom-

* As it is troublesome to crowd the pages with frequent references, it may be mentioned that the most noteworthy of these works are :—"*Traité des Arts Céramiques*," by M. Brongniart, 1844; "*Chemical Technology: or Chemistry applied to the Arts and to Manufactures*," by Drs. Knapp, Ronalds, and Richardson, 1848; "*Treatise on the Manufacture of Bricks and Tiles*," by E. Dobson, 1850; "*Dictionary of Arts, Manufactures, and Mines*," by Dr. Ure, 1853; "*Brick-making*," by H. Chamberlain, 1856; "*Hand-book of Chemistry*," by Messrs. Abel and Bloxam, 1858; "*Economy of Fuel*," by T. S. Prideaux; "*Advanced Text Book of Geology*," by Dr. Page, 1859; "*The Iron Manufacture of Great Britain*," by W. Truran, 1862; "*Metallurgy*," by Dr. Percy, 1864; "*Reports on the Birmingham and Midland Hardware District*," Edited by S. Timmins, 1866; "*Manual of Civil Engineering*," by W. J. M. Rankine, 1867; and "*On the Regenerative Gas Furnace as applied to the Manufacture of Cast Steel*," by C. W. Siemens, 1868.

posed rock, characterized by a very minute division of constituent particles) they are tough and plastic—differing from mud in these respects, as well as in the absence of vegetable and animal matters. The plasticity and tenacity of argillaceous earths are due to the prominence of the ingredient alumina (which has a strong affinity for water), and are diminished by the presence of iron, lime and magnesia. Clays appear to be the result of the slow decomposition by water of felspar or some similar material, containing either potassa or soda.

The so-called Fire-clays owe their refractory properties to a variable absence (differing, that is to say, in different clays) of lime, oxide of iron, and the alkalies of magnesia, potassa, and soda. The two last-named constituents produce in the clay a considerable degree of fusibility: lime, oxide of iron, and magnesia, exercise a much weaker effect.* In refractory bricks, formed of baked fire-clay, the silica may be considered as a passive ingredient, acting mechanically to prevent excessive contraction, whilst the alumina forms the cement which binds the particles together.

The following is a list of the usual constituents of fire-clay, with their respective chemical symbols :—

Silica (or silicic acid)	$Si\,O_2$
Alumina (or sesqui-oxide of aluminum)	$Al_2\,O_3$
Peroxide (sesqui-oxide or red oxide) *of Iron*	$Fe_2\,O_3$
Lime (oxide of calcium)	$Ca\,O$
Magnesia (oxide of magnesium)	$Mg\,O$
Potassa (oxide of potassium)	$K_2\,O$
Soda (oxide of sodium)	$Na_2\,O$

and the following table details, for the sake of example, their proportions found in chance samples of several well-known classes of English fire-brick :—

	Silica.	Alumina.	Peroxide of Iron.	Lime.	Magnesia.	Potassa.	Soda.	Titanic Acid.	Total.
Stourbridge	65·37	26·48	5·68	·28	·33	1·26	·30	·30	100·00
Plympton, Devonshire	74·02	21·37	1·94	·40	·36	·82	·09	—	100·00
Newcastle-on-Tyne	64·63	29·78	3·23	·42	·41	1·09	·24	·20	100·00
Burton-on-Trent	58·08	36·89	2·26	·55	·14	·20	1·88	—	100·00
Wortley, near Leeds	65·25	29·71	3·07	·40	·61	·43	·12	·41	100·00
Poole, Dorsetshire	59·35	34·32	2·35	·43	·22	3·33	—	—	100·00
Hedgerley, Buckinghamshire	84·65	8·85	4·25	1·90	·35	—	—	—	100·00
Kilmarnock, Ayrshire	58·92	35·65	2·49	·39	·35	1·14	1·06	—	100·00
Dinas, Glamorganshire	97·62	1·40	·49	·29	—	·10	·10	—	100·00

* The presence of a small quantity of lime uniformly diffused through a fire-clay may not be injurious, and may possibly tend to render the substance of a crucible made of such clay compact and close in grain. The presence of potassa or soda in sensible proportions in a fire-clay would certainly make it less refractory; but in the proportion in which they appear to exist in some of the best fire-clays, their effect may be beneficial rather than otherwise, by soldering, as it were, the particles firmly together.—Dr. Percy's *Metallurgy*, p. 218.

It should be observed, however, that the infusibility of any substance depends, not merely upon the chemical natures of its constituents, but also upon the manner in which those constituents are combined with one another. For example, granite *per se* is infusible at ordinary high temperatures, whilst pounded granite (or, in other words, a fine powder of quartz, felspar, and mica, mixed in the same proportions) can be readily melted by the same degree of heat. The porosity in structure brought about by a coarseness of elementary particles would seem to add to the chemical infusibility of a material.

A most important physical peculiarity of clay—second only in importance to the property of plasticity—is its behaviour on exposure to high temperatures. It is well known that, as a general rule, all bodies are expanded by heat. Clay, however, appears to be an exception to this rule, being a mechanical mixture and not a homogeneous body; and it was observed by Mr. Wedgwood* that alumina, or clay in which alumina predominates, on being exposed to a red heat, begins to contract, and, as the heat increases, continues to contract regularly until it finally vitrifies, and so (by its permanent diminution in bulk) furnishes an approximate indication of the temperature to which it has been subjected.

Hence the Wedgwood pyrometer, which, by a comparison of the diminution in diameter of small cylinders of aluminous porcelain clay, placed between cylindrical brass rods forming a graduated gauge, supplies an empirical text of the degree of heat which those cylinders have sustained. It is proper, however, to remark that, as clay is a heterogeneous substance, and its contractions are not of necessity regular at different temperatures, this pyrometer—though useful for most practical purposes—fails to record the degrees of heat with precise accuracy; and there has yet to be devised a thermometer which will indicate with absolute exactness the very high degrees of furnace temperature.

Again, the moulds of bricks are usually made larger than the intended products by about $\frac{1}{10}$ or $\frac{1}{12}$ of each dimension, that being the ordinary proportion in which the dimensions of the brick shrink in burning.

The cause of this strange property of clay is, I believe, still a matter of question. By some it is supposed to result from an expulsion of the water of combination, and a consequent contraction of the primary pores, which produces an increased density of the mass. By others it is ascribed to an actual rearrangement of the constituent atoms by the influence of heat, which brings them into more intimate union. But, whatever be the cause, the property is important and noteworthy in its bearing upon the present subject of investigation.

Fire-clays able to resist exposure to a high temperature without melting or becoming, in a sensible degree, soft and pasty, occur in various geological formations, and they abound in the coal measures of the carboniferous system. The following are a few of the best known localities in this country whence fire-clay is extracted:—The valley in Derbyshire between Burton-on-Trent and

* Communicated to the Royal Society in a paper dated May, 1782. See "Philosophical Transactions," Vol. 72, page 305.

Ashby-de-la- Zouch; the Stourbridge district, in Worcester and Staffordshire (including Dudley, Tipton, Gornal, &c.); Newcastle-on-Tyne, in Northumberland; Wortley, near Leeds, in Yorkshire (including Elland, Storr's Bridge, Stannington, &c); Wolverhampton, in Staffordshire; Poole, in Dorsetshire; Newport, in Monmouthshire; Kilmarnock, in Ayrshire; and Glenboig, at Coatbridge, near Glasgow, in Lanarkshire. To these should be added, as sources of some of our most celebrated fire-bricks, the aforesaid Dinas rocks in the Vale of Neath, Glamorganshire; the *kaolinitic* refuse from porcelain clay at St. Austell's, Cornwall, and Plympton, Devonshire; and a peculiar stratum of sandy loam, known as "Windsor loam," overlying the chalk at Hedgerley, a village about five miles north of Slough, Buckinghamshire, whose "red rubbers," were in the times of our grandfathers, thought to possess surprisingly refractory powers.

In the following table is shown the per-centage of the three most important constituents of these different kinds of fire-bricks, which have been practically tested in the Royal Arsenal furnaces, and analysed by Mr. Abel, F.R.S., Chemist to the War Department. The makers' names are, for obvious reasons, omitted; but samples of most of these fire-bricks are to be seen in the School of Military Engineering at Chatham:—

	Maker.	Silica.	Alumina.	Peroxide of Iron.	Alkalies, Waste, &c.
Stourbridge	A	65·65	26·59	5·71	2·05
	,,	67·00	25·80	4·90	2·30
	,,	66·47	26·26	6·63	·64
	B	58·48	35·78	3·02	2·72
	C	63·40	31·70	3·00	1·90
	,,	65·08	27·39	3·98	3·55
	,,	65·21	27·82	3·41	3·56
	D	65·50	27·35	5·40	1·75
	,,	63·42	31·20	4·70	·68
	E	74·97	21·78	1·77	1·48
Newcastle	F	59·80	27·30	6·90	6·00
	G	63·50	27·60	6·40	2·50
	,,	65·16	30·02	3·26	1·56
	,,	65·16	31·52	3.26	·06
	H	64·95	28·85	3·50	2·70
	J	65·52	28·84	2·38	3·26
	K	64·60	28·70	4·80	1·90
Burton-on-Trent	L	56·63	35·31	2·99	5·17
	M	57.78	35·78	3·81	2·63
Wortley	N	65·20	29·69	3·07	2·04
	O	67·80	29·20	1·80	1·20
Poole	P	68·60	23·60	4·70	3·10
Plympton	Q	75·89	21·61	1·96	·54
	,,	73.50	22·70	1·70	2·10
	,,	76·70	20·10	1·70	1·50
Hedgerley	R	84·65	8·85	4·25	2·25
Holytown	S	59·48	31·45	6·90	2·17
Dinas	T	96·20	2·00	·28	1·70
	U	96·00	1·51	·50	1·99
Kilmarnock	V	59·10	35·76	2·50	2·64
	W	57·50	34·90	1·80	5·80
Glenboig	X	62·50	34·00	2·70	·80

Experience with these samples justifies the general assertion that the refractory values of fire-bricks vary inversely with the amount of iron contained in them; and, as a general rule, the presence of 6 per cent. of peroxide of iron warrants the absolute rejection of a fire-brick. This component usually takes the form of little black specks or mottled particles, which are embedded in the material, and can be plainly detected on breaking the brick.

The essential qualities of a good fire-brick may, I think, be classified as follows:—*Infusibility, regularity of shape, uniformity of composition, facility for cutting, strength,* and *cheapness.*

The property of *infusibility* has already been touched upon in this paper; and it seems to forbid in the brick's composition so much as even 5 per cent of peroxide of iron, or 3 per cent. of combined lime, soda, potassa, and magnesia. Generally speaking, a fire-brick should contain either silica or alumina in excess, according as it is intended for exposure to extreme heat, or for a possible contact with metalic oxides, which would exert a chemical re-action, decomposing it and acting as a flux. Thus, in theory, the arches of a furnace should be built of siliceous bricks; its sides, bridge, and neck, of aluminous bricks. Dr. Percy considers (*Metallurgy*, p. 235) that, to boast properly of the quality of infusibility, a fire-brick must well resist sudden and great extremes of heat; it must support considerable pressure at a high temperature without crumbling; it should not melt or soften in a sensible degree by exposure to intense heat long and uninterruptedly continued;* and it should withstand, as far as practicable, the corrosive action of slags, rich in protoxide of iron. He recommends, as a test, that the fire-clay should be formed into small sharp-edged prisms which, on being enclosed in a covered crucible and subjected to an extreme temperature in an air or blast furnace, would denote a very high degree of refractoriness if the edges remained sharp, an incipient fusion of the material if the edges were rounded, and a thoroughly inferior quality of the fire-clay if the prisms were melted down. M. Brongniart recommends the following process of test (*Traité des Arts Céramiques*, tom. 1, p. 342): "Si on veut juger la qualité réfractaire d'une brique, c'est de faire un petit massif de six ou huit de ces briques sur deux rangs, et de l'exposer, un rang en avant, dans un four à porcelaine à l'entrée du feu dans le four. Le poids affaisera les inférieures si elles sont seulement ramollisables. Le rang antérieur ne doit pas entrer dans le jugement; il est toujours attaqué, quelque réfractaire qu'il soit; mais il sert à garantir le rang postérieur de l'action de la potasse des cendres à laquelle la terre la plus réfractaire ne peut résister. C'est donc sur les altérations de ramollissement, de fusion, ou de boursouflement du rang postérieur qu'on peut juger la qualité réfractaire d'une brique. Aucun moyen d'analyse ou d'essai en petit ne peut suppléer à ces véritables essais techniques." It may be remarked, however that in this investigation, analysis, theory, and practice, nearly always

* Une des qualités importantes et recherchées dans les briques qui doivent servir à construire ou au moins à faire la chemise intérieure des fourneaux et fours qu'on chauffe à très-haute température, c'est la propriété de résister sans se fondre et même sans se ramollir à ces hautes températures plusieurs fois répétées ou longtemps continuées. On appelle généralement briques *réfractaires* celles qui possèdent complétement cette inaltérabilité par l'action d'un feu violent.—*A. Brongniart.* (Traité des arts céramiques, ou des poteries considérées dans leur histoire, leur pratique, et leur théorie.)

agree pretty closely. In many works there is adopted the rough and ready, but very efficient, mode of comparing the relative qualities of fire-bricks by placing them side by side upon the bridge of a reverberatory furnace, where they are subjected to the same heat and the same corrosive action of the fuel, and show very clearly, after a few days or weeks of firing, which brick can best withstand these destructive influences under precisely similar conditions. I think that this test is even superior to those suggested above. The corrosive action of suspended coal dust in fluxing and gradually cutting away the exposed surfaces of brickwork is extraordinarily great—even superior to the disintegrating influence of extreme heat. Hence, a great claim to economy of the Siemens' Regenerative Gas Furnace; and Mr. Siemens affirms that the heat at which a suitably designed furnace can be worked is limited in practice only by the difficulty of finding a material sufficiently refractory of which it can be built.

Regularity of shape requires that the brick's opposite sides should be truly parallel planes (excepting, of course, the special cases where key hollows are left) and the arrises sharp right-angled edges. The necessity for this requirement is obvious. In all forms of brickwork regularly-moulded bricks produce even joints, prevent settlements, and effect economy as well as stability in the work. But in fire-brickwork, especially, an uniform shape of each individual component of the furnace permits, under extreme changes of temperature, an uniform expansion or contraction in all directions: it tends to preserve the relative proportions, and thus to ensure the general stability, of the entire mass of the brickwork.

Uniformity of composition. The brick, on fracture, should present a compact uniform structure—not necessarily close, for indeed some maintain that a coarse grit of texture is the chief requisite, and that a close uniform structure, though pleasing to the eye, is not favourable to the refractory powers of a fire-brick, since the particles should have a facility for contraction or expansion under heat, and the air cavities act as valuable non-conductors of heat. But the brick should be free from stones, cracks, and irregular air-hollows; and, on being struck, it should emit a clear ringing sound. The existence of this property usually involves that of the next.

Facility for cutting, i.e. a capability for being easily dressed with perfect accuracy, so that the brick shall not require a very violent blow, or split in a direction other than that intended, or fall to pieces under a trowel. This property is certainly an advantage in both building and repairs; but that it is not of paramount importance may be inferred from the fact that the best fire-bricks ever used in the Manufacturing District least fulfil this condition; yet no one—not even the bricklayers whose tools suffer from the bricks' excessive hardness—would discontinue their use on that account. A fire-brick should never have its dressed surface, but only its " fire-skin" exposed to the furnace flame, for reasons similar to those against the exposure of the rubbed surface of an ordinary building brick to the weather. Hence it is desirable to employ as many forms of differently-moulded brick as possible, and the accompanying diagrams show the dimensions of the special shapes found most convenient in actual practice. Though it is impossible to propound an exact rule as to the per-centage of cost of labour and materials in furnace work, their relative proportions may be roughly said to average 33 to 67 in new work, and 60 to 40 in repairs, such as cutting out bridges, clearing the necks, slag-holes, &c.

Strength is obviously necessary to enable the brick to avoid breakage in transport, and to withstand the pressure and cross strains to which it will be subjected when built into the work. It is stated by Rankine (*Manual of Civil Engineering*, p. 367) that the resistance to crushing by a direct thrust—the bricks being set on edge in an hydraulic press—is per square inch, in weak red bricks, from 550 lbs. to 800 lbs.; in strong red bricks, 1100 lbs.; in fire-bricks, 1700 lbs. But experiments recently made in the Royal Arsenal upon isolated cubes of 1½-in. side, cut from fire-brick "soaps," and placed between small squares of sheet lead, gave the following results:—

		Cracking Weight.* lbs. per sq. in.	Crushing Weight.* lbs. per sq. in.
Stourbridge	A	1478	2400
Ditto	D	1156	2245
Newcastle	G	889	1512
Plympton	Q	1689	2666
Dinas	U	1123	1288
Kilmarnock	W	2134	3378
Glenboig	X	1067	1556

and the average crushing weight of ordinary stock bricks was found to be from 666 to 866 lbs. per square inch. Hence, all fire-bricks known may be said to have a strength far in excess of that which would be ever required of them in actual work.

Cheapness may appear an impolitic, and therefore unworthy, consideration, but it practically determines the selection of nine-tenths of the fire-bricks used in this country. For example, the freightage to London per ton, (from 320 to 370 9-inch bricks) costs, on an average, 5s. 6d. from Newcastle, and 13s. from Stourbridge. Hence the great advantage possessed, *cæteris paribus*, by the manufacturers at the former place over those at the latter. And supposing the cost in London of one class of fire-bricks to be one-half that of another, and the above statement to be true—viz., that in the cost of new work, labour : materials :: 33 : 67—it will be readily understood that, from a monetary point of view, it might be perfectly immaterial to the furnace owner whether he used the cheap or the dear fire-bricks—always supposing that the former be not so bad as to disintegrate and drop into the metal, and that a comparatively frequent "standing" of some furnaces in his establishment were of no great consequence to his pocket. But, in point of fact, the *pros* and *cons* of this question are seldom so nicely balanced as in the hypothetical case I have

* The term "cracking weight" is meant to imply that which produced the first perceptible crack in the material. The "crushing weight" is that which caused pieces of the exposed surfaces to crumble and flake off.

assumed, and the invariable experience of the Manufacturing District is that the best fire-bricks prove always to be ultimately the cheapest.

I now propose to attempt some general descriptions of the usual processes in vogue for making certain of the best-known classes of English fire-bricks. In this manufacture a more than ordinary care is found requisite to ensure an uniformly regular success from its processes, and it should be observed that there is almost as slight a similarity between the modes of manufacturing fire and building bricks as there is analogy between their uses. With the former use involves incessant repair and, after a few months' wear in a busy furnace, entire renewal: with the latter, even if of worthless quality, a builder, careless of reputation and indifferent to the possible discredit of distant failures, can often construct without fear of immediate detection. Yet, even with this practical check upon quality, all experience in fire-bricks induces a certain wise toleration, so that isolated or exceptional cases of failure should not be allowed to justify the sweeping condemnation of an entire class.

In the following remarks care will be taken, for obvious reasons, to avoid identifying those makers who have courteously allowed the writer to inspect their works. Yet the official recommendations of a certain agent's fire-lumps (I.G.F. Circular No. 43, dated 20th November, 1862), taken in company with the experience of some the most eminent iron and steel firms of Sheffield, may be allowed to sanction the opinion that a very high degree of excellence should be attached to the fire-clay manufactories of the Burton-on-Trent district. With these manufactories, therefore, it is proposed to begin.

Burton-on-Trent.

The clay is dug, at a depth below the surface of about 20 feet, from open pits whose sides display the following strata:—

	Thickness. ft.	in.
1. A common earthy or brick clay (burns white)	6	0
2. A kind of coal, locally termed "smut"	1	0
3. A kind of marl, locally termed "clunch"	6	0
4. A kind of coal, locally termed "smut"	0	6
5. Marl	6	0
6. Fire-clay:—a bluish-black or slate-coloured clay, of which the upper stratum 10 in. or 12 in. thick (locally termed "top black") is best	6	0
7. A kind of shaly coal, locally termed "smut"	1	0
8. Bottle-clay, for sewage and drain pipes	9	0
9. Iron-stone and "smut"	2	0
10. Pot-clay, for yellow ware,	succeeds.	

The fire-clay is worked up into bricks as fast as it is obtained from the pits. It is not here the custom, as in many districts, to "weather" the clay by long exposure before use, but it is sometimes moistened with water in order to lay the dust. It is usually transported from the pits, and through the works, in trucks upon a tramway of 1-in. rails and 18-in. gauge; but the wire-rope overhead transport system* is being generally substituted, and this will permit the

* Wire Tramway Company, 21, Gresham Street, Old Jewry, London, E.C.

easy transport of about a 4 cwt. load in each of the "trunks" or boxes, upon an endless steel wire rope suspended from poles, passing over Fowler's clip drum pullies, and worked by small portable steam engines.

The clay is pulverized in Carr's Disintegrator,* composed of four cylindrical cages, 6 ft. 3 in., 5 ft. 7 in., 4 ft. 9 in., and 4 ft. 7 in. in diameter, arranged concentrically on wrought iron disc plates, so that the steel bars or beaters are about 4 inches apart and 1 foot 4 inches wide. These sets of beaters revolve in opposite directions, by means of an open and a crossed driving band working their disc axles, so that the first and third cases rotate in a direction contrary to that of the second and fourth; and they make about 200 revolutions a minute. The clay is lifted and delivered through a hopper into the interior of the machine, (whose capacity is about 31 cubic feet,) by means of buckets upon a "Jacob's ladder'" endless band, 10 inches wide. It is then driven through the mill and ejected from it in a finely granulated state, by centrifugal force, at the rate of from 20 to 30 tons an hour. The clay is in this manner sufficiently pulverized to render a riddle unnecessary, if meant for fire-bricks; but if for mortar or cement clay, it is passed through a wire mesh of 5 or 6 to the inch. The chief advantages of this machine over the ordinary "edge-runner and pan" system of a mortar mill, consist in its ability to pulverize a moist plastic clay as well as a dry clay, and in its power to disintegrate about 200 tons of clay per diem, in which time the roller and edge runner process can, with the same steam power, grind only about 50 tons.

The bricks are fired in Hoffmann and Licht's Annular Kilns, where, in successive chambers (each 15 feet wide, 8 feet 6 inches high, and holding about 20,000 bricks) different sets of bricks are dried, heated, burned, and cooled, by the currents of air feeding and escaping, with the products of combustion, from the same one fire. This form of kiln is found most economical, in consequence of—*firstly*, the fuel being burnt with air already at an incandescent temperature; and, *secondly*, the waste heat from both cooling and burning goods being entirely utilized in drying the new fresh bricks about to be burnt, and raising them to a high temperature. The consumption of fuel in this form of kiln is therefore very small, in comparison with that in one of the ordinary form of construction, and it is found that the burning of 1000 bricks in the annular kiln requires only $2\frac{1}{2}$ cwt of Stavely dust coal, at 5s 6d. a ton, instead of 20 or 25 cwt. of large "Grosby Slack" coal, at 7s. a ton. The difference of cost for coal alone amounts therefore to about 8s. per 1000 bricks, and the saving of labour is also very considerable. The bricks so fired are peculiarly well formed and well burnt; the former, because they escape the additional handling and transport required by the drying-shed process; the latter, because they are practically annealed by the gradual heating and gradual cooling in the successive processes of drying, heating, firing, and cooling, which extend over a period of about three weeks.

Stourbridge. In the Stourbridge fire-clay district, situated about 20 miles south-west of Birmingham, the mechanical contrivances for the

* Patentee, Thomas Carr, Richmond Road, Montpelier, Bristol.

brick manufacture are of less novel description than those mentioned in the foregoing account. For upwards of three centuries the Stourbridge fire-clay has been celebrated; and in 1566 a lease of land near the present railway station was granted for the purpose of getting and digging pot-clay for glass manufacture, which had been introduced into England by refugees from Lorraine, about 10 years previously. In Dr. Robert Plot's "Natural History of Staffordshire," published in 1686, the Stourbridge fire-clay is thus spoken of (chap. 3, par. 24, page 121):—"But the clay that surpasses all others of this *County*, is that at *Amblecot*, on the banks of the *Stour*, in the parish of *Old Swynford*, yet in *Staffordshire*, in the lands of that judicious and obliging Gent. the Worshipfull *Harry Gray* of *Enfield* Esq.; whose beautifull Mansion, perhaps the best situat of any in the *County*, is here represented *Tab.* 7. I say the most preferable *clay* of any is that of *Amblecot*, of a *dark blewish* colour, whereof they make the best *pots* for the *Glass-houses* of any in *England*: Nay so very good is it for this purpose, that it is sold on the place for sevenpence the bushell, whereof Mr. *Gray* has sixpence and the *Workman* one penny, and so very necessary to be had, that it is sent as far as *London*, sometimes by *Waggon*, and sometimes by *Land* to *Beaudley*, and so down the *Severn* to *Bristol*, and thence to *London*: the goodness of which *clay*, and cheapness of *coal* hereabout, no doubt has drawn the *glass-houses*, both for *Vessells* and *broad glass*, into these parts; there being divers set up in different formes here at *Amblecot*, *Old-Swynford*, *Holloway's-end*, and *Cobourn brook*."

The Stourbridge fire clay district, including Amblecote, Brierley Hill, and the Lye, covers an area of from eight to nine square miles, with six fire-brick manufactories in Worcestershire, and seven in Staffordshire. From the pits on these works about 100,000 tons of fire-clay are annually raised, and the supply of fire-bricks has increased within the last fifteen years from fourteen to thirty millions per annum. In the neighbourhood, the Quarry Bank Church is built entirely of Stourbridge fire-bricks; the Brockmoor Church is built partly of fire-bricks and partly of blue bricks; and fire-bricks have been extensively used in the construction of the railway stations between Stourbridge and Birmingham.

A few miles distant from Stourbridge are the fire-brick works of Dudley, Gornal, Hanford, Basford, Tunstall, Tipton, &c., the quality of whose clay, for refractory purposes, is very naturally disparaged by the manufacturers at Stourbridge proper.

The processes through which the clay passes during its manufacture into fire-bricks are nine in number, viz., digging, weathering, grinding, sifting, tempering, pugging, moulding, drying, and burning.

The Stourbridge fire-brick black clay, or coal-measure marl—a species of shale or slate clay—is dug from pits (whose shafts are 6 ft. or 8 ft. in diameter, and steined) varying in depth from 120 to 570 feet. It is generally found below three workable coal measures, between marl or rock and an inferior clay. The former, overlying the fire-clay, is generally about 48 feet thick. The fire-clay seam averages 3 feet in thickness, never exceeding 5 feet, and thinning down to 5 or 6 inches when close to faults or small disturbances in the measures. The middle stratum of the seam is always selected for the fire-clay, the top and bottom being thought too "strong." After being raised from the pits, the fire-clay is picked over by women, who select the best lumps or "kernels" for glass-house pots, and reject for stains and mineral impurities. The pot clay is only found in small quantities—about sufficient for the glass manufactories—and costs on the spot 55s. a ton, whereas ordinary fire-clay costs on the spot only 10s. a ton; and four tons of clay (about 3½ cubic yards) are required to make 1,000 9-inch fire-bricks, whose local price is 50s. Some of the glass-house pots recently made for one of the large plate-glass manufacturers at Ravenhead, weighed as much as 30 cwt. each when dry, and stood 6 feet high.

The clay is exposed in spoil heaps, over as large an area as can be secured, for from 3 to 18 months, according to the state of the weather. The action of frost, as with ordinary brick earth, is of great service in disintegrating the compact tough lumps of clay, and in dry weather the clay is frequently watered. In very wet weather, a three months' exposure will suffice for its proper "mellowing" or "ripening"; it ultimately slacks and falls to pieces. When new it is termed in the local phraseology "short and rough"; after due exposure it becomes "mild and tough." On some of the works the spoil heaps of clay contain over 10,000 tons, and it is estimated that 7 tons measure about 6 cubic yards.

After sufficient weathering, the clay is ground in a circular pan by two rollers or cylindrical stones, shod with iron rims 2½ inches thick, and weighing from 2½ to 3¼ tons apiece. They are driven by steam power.

After being ground, the clay is carried on an endless band to a "riddle" of about

4 or 6	mesh to the inch	for	fire-bricks,
6 or 10	,,	,,	fine cement clay,
12 or 14	,,	,,	glass-house pot clay

the larger sized mesh being used for the sifting of the clay in wet weather. The large particles, which will not pass through the "riddle," are carried back on an endless band to the pan, and there re-ground.

As a general rule, it is only for very large fire-brick lumps (such as blast-furnace "tymps," 40 in. long and 12 in. by 10 in.) that re-ground pots, crucibles, or bricks—locally termed "grogg"—are added to the clay before grinding; and fire cement clay is always ground pure.

After passing through the "riddle," the clay is tempered, or brought to a proper degree of plasticity by the addition of water.

It is then thoroughly stirred and kneaded, in a circular cast iron pug-mill, by revolving knives projecting from a vertical shaft driven by steam power. The clay is forced down by the obliquity of the rotating knives, aud streams slowly from a hole near the bottom, whence, after being cut by wires into parallelopipedons, it travels on in an endless band to the moulding sheds.

The bricks are then moulded by hand, in the usual manner, (in moulds 10 in. by 5 in. by 3 in., or thereabouts), and dried at a temperature of 60 or 70 degrees, in sheds about 120 feet long and 30 ft. wide, beneath whose floors run longitudinally two flues heated by small furnaces. In fine weather, however, the sun heat is made to economise fuel.

The bricks are burnt in circular domed kilns, or cupolas, locally termed "ovens," where they remain for from 8 to 14 days; being fired with the real intensity of flame, or white heat, for about 4 days and 3 nights: they usually require 7 days to cool down. The fire is slowly increased, and gradually lowered, the time of burning being regulated by the kiln-man in charge, who inspects the baking bricks from time to time through holes in the domed roof of the "oven." The chimney stack is on the outside of the kiln, and the flame burns with a down draught, descending through holes in the floor—the fire-holes being merely openings left in the thickness of the wall of the kiln, and protected from the wind by buttresses long enough to allow room for the firemen to attend the fires. The coal is of course obtained from the pits which provide the clay. Most of the kilns hold each 12,000 bricks, but some are made large enough to contain each 30,000 or 35,000 bricks, the capacity of a kiln being roughly calculated upon the assumption that 10 bricks require one cubic foot of space in the kiln.

For conveyance of the clay and bricks about the Stourbridge works, little trucks called "skips" are employed in the pits, and throughout the brick fields. Their platforms, standing 1 ft. high, are 4 ft. square, and consist of 1½ inch planks. Their wheels, of cast iron, are 10 inches in diameter, with 2-inch axles. The rails, 2 feet apart, consist of ¼-inch wrought iron angle rails, 3 inches wide and 1½ inches high.

The colour of Stourbridge fire-bricks is a "foxy" reddish or yellowish gray; and it is noticeable that the colouring matter of this material consists essentially in the amount of ferric oxide it contains. "I remember," says Dr. Bancroft (when treating of iron in his *Philosophy of Permanent Colours*), "having been told by Mr. Wedgwood that nearly all the fine diversified colours applied to his pottery were produced only by the oxides of this metal."—(Miss E. Meteyard's *Life of Josiah Wedgwood*, 1866; vol, ii. p. 74.)

Newcastle. The mode of fire-brick manufacture in the Newcastle district differs from that of Stourbridge in a very few and unimportant particulars. The clay, in a spoil heap of 30,000 tons, is often weathered for seven or eight years, during which time it is picked over by boys, who remove pyritous fragments exposed on disintegration. When required for fire-bricks, it is ground by cylindrical edge-stones, weighing 3 tons each, in a revolving pan, or else upon the ground, and then passed through a wire "riddle" of 6 or 8 mesh to the inch. Throughout the works are 18-inch tramways, and pony trucks convey the materials from place to place. After tempering, pugging, moulding, and drying, the bricks are burnt in kilns about 15 ft. by 14 ft. by 10 feet high, holding each 15,000 bricks. They are fired for eight or nine days, during which time 5 tons of coals are consumed. The flame and hot air pass from a fire-box at one end of the kiln to outlet flues at the other end of it, and thence into an external chimney. About 80 millions of fire-bricks are produced annually from the Newcastle district, *i.e.* nearly three times the annual supply of the Stourbridge works.

St. Austell's and Plympton. Very excellent fire-bricks are made from the refuse of *Kaolin* or china clay, found in Cornwall and Devonshire. Kaolin is produced by the disintegration of "pegmatite," or felspathic granite, under the action of the carbonic acid and moisture of the atmosphere: it then becomes a basic silicate of alumina. The kaolinitic fire-bricks, containing very little iron or lime (see analyses on page 17) possess extremely refractory powers and have, in fact, been found in the Royal Arsenal air furnaces to be equal or superior in this respect to any other known fire-bricks in the kingdom. With their rivals they compare as favourably for economy as for endurance; but the former is, of course, a specially local advantage, which might possibly disappear in another district.

Kaolinitic fire-bricks enjoy, however, a very high reputation in lead smelting furnaces, converting vessels of the Bessemer steel process, the retort furnaces of gas-works, kilns for burning iron pyrites, &c., &c. For the moderate heat to be withstood by ordinary boiler seatings, a burnt compound of kaolin, sand, and local clay, in equal parts, is found to be as good as the fire-lumps ordinarily employed. The refractory powers of a clay will, of course, be always increased by the addition of pure siliceous sand, which can be produced by grinding sandstone, if it is not obtainable in a state of nature.

Hedgerley. The so-called fire-bricks of Hedgerley in Buckinghamshire, are made from a stratum of very sandy slate-coloured clay, found at a depth below the surface of about 40 or 50 feet, overlying the chalk and supporting the ordinary reddish brick marl or London clay. They consist mostly of sand, cohering by means of a very small proportion of alumina, and their siliceous nature makes them chiefly useful for rubbed and gauged brick-work.

After due exposure to the weather for from 3 to 12 months, the clay is mixed with water in a wash-mill, or circular trough, where it is worked by harrows drawn by horses, until it is thoroughly mixed up into a fluid state. It is then strained through gratings (16 mesh to the inch)—which intercept all impurities and small rag stones, locally termed "srap"—into settling tanks 3ft. deep and about 10 yards square, whence the water is drained off, after the subsidence of the washed clay. The clay is then twice passed through a pug-mill worked by horse power. The bricks are moulded, dried, and fired, like ordinary stock bricks. They lose about one-fourth of their weight in drying, and one-twelfth in burning; the latter process necessitates a temperature of some 20° Wedgwood, whereas the Stourbridge fire-bricks require upwards of 80° Wedgwood.

It must be confessed, as the result of real experience, that the Hedgerley bricks, as fire-bricks, contrast very unfavourably with those produced from the other localities. It is not too much to say that, in reverberatory furnaces, they are almost worthless; and, in all probability, their employment in boiler-seating flues, or similarly cool situations, led to their high reputation in olden times, when they were thus spoken of:—" For the making of such bricks as will stand the fiercest fires, Sturbridge clay or Windsor loam are esteemed the best." —(*Encyclopædia Britannica*, Ed. 1797); and, "At Hedgerley, a village near Windsor, an excellent brick is made, capable of resisting the greatest violence of fire. These are called Windsor Bricks or Fire-Bricks."—(*Course of Practical Architecture*, by Colonel C. W. Pasley, R.E.); and again, an article by Mr.

Peter Barlow, F.R.S., on "Manufactures," in the *Encyclopædia Metropolitana*, 1845, contains the following passage, (copied apparently from Rees' *Cyclopædia*, 1819):—"The Windsor bricks, or fire-bricks, which are made at Hedgerley, a village near Windsor, are red bricks, containing a very large proportion of sand; these are used for coating furnaces, and lining the ovens of glass-houses, where they stand the utmost fury of the fire."

Dinas. On the other hand, the Dinas fire-brick is well worthy of attentive consideration, if, indeed, solely for the reason that it is, in the opinion of Mr. C. W. Siemens, F.R.S., "the only material of those practically available on a large scale that I have found to resist the intense heat at which steel-melting furnaces are worked."* Now, the average heat of a steel-melting furnace, measured by electrical resistance, may be accepted as 2200° Centigrade (= 3992° Fahrenheit), and that of the ordinary air furnace, at welding heat, as 1600° Centigrade (= 2912° Fahrenheit). In the very intense heat generated by the former, the Dinas bricks will last, it is found, for four or five weeks, though their thickness will, in that time, have been even reduced from 9 to 2 inches. But these extraordinary results, it should be remembered, have been only obtained in the Siemens' Regenerative Gas Furnace, wherein—the flame being quite pure and free from the suspended dust which is usually borne from the fuel by the keen draught of air through an ordinary reverberatory furnace—the brickwork is not fluxed on its surface and gradually cut away thereby, but it fails, if at all, from a general softening and fusion throughout the entire mass. For the ordinary puddling, mill, or air furnace, the Dinas bricks—notwithstanding their ability to resist very high temperatures—are somewhat troublesome in actual practice. They are very friable, porous (and thus imbibe moisture freely), they swell extremely with heat, and do not contract to their original dimensions. If allowed to cool down (and it is customary, in most works, to let the furnaces "stand" from mid-day on Saturday till mid-day on Monday) they are apt to crack, flake off fragments, and then fly to pieces, in consequence of the decrepitation of portions of the quartz composing them. From their extreme tenderness, they are unlikely to prove durable if applied in portions of furnaces where they would be subjected to much mechanical wear. Yet their refractory powers are remarkably great; and they bear a very high reputation with many owners of copper-smelting, iron, glass, and gas works, coke ovens, &c., and they seem to be highly esteemed for the arches of reverberatory furnaces in the copper works of Swansea, at Middlesborough, and at Ebbw Vale. The tabulated analyses on p. 17, show the high per-centage of silica which these bricks contain; and from their siliceous nature it is obvious that they should not be exposed to the action of slags rich in metallic oxides, or to the fumes from lead ores, or to proximity with alkaline substances generally.

The Dinas fire-brick manufacture was regularly established 48 years ago, at the instance of the inventor, Mr. W. Weston Young, a land surveyor of Newton Nottage, Glamorganshire, who, in 1820, discovered a method of producing a brick from the Dinas rock in the Vale of Neath. This rock, consisting

* Lecture delivered before the Fellows of the Chemical Society on the 7th May, 1868, by C. W. Siemens, F.R.S., Memb. Inst. C.E.

of almost pure silex, rests upon the limestone, so that the raw material contains a small proportion of calcareous matter and a very minute quantity of metallic compound, either iron or copper.

The rock, after being quarried, is subjected to a rude crushing operation between iron rollers, which reduces it to a coarse powder; and this is mixed with a little water to give coherence to the mass, and with about 1 per cent. of lime, which, in the process of firing, exercises a fluxing action on the surfaces of the quartz fragments, and so causes them to agglutinate. The particles of the resultant clay are so large and coarse that it is impossible to mould it by hand; it is, therefore, pressed by a machine into iron moulds, and the workmen find it even necessary to use stout leather gloves as a protection against the sharp edges of the rock's fragments. The bricks, laid on the iron plates which supported them when compressed, are dried upon floors warmed by flues beneath, and are then baked for 6 or 7 days in circular domed kilns, holding each about 32,000 bricks.

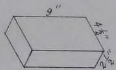
The foregoings remarks may serve to show that the manufacture of fire-bricks in the present day is a subject embracing a great diversity of treatment from local circumstances, the varying compositions of the clay, and the different mechanical contrivances introduced into the several processes of formation. With them may be contrasted the remarks of M. Brongniart, a quarter of a century ago:—" On a fait un grand bruit de la fabrication de ces briques réfractaires, et cependant leur principe de fabrication est des p'us simples et des plus facilement applicables. Il se réduit à posséder une argile déjà très réfractaire par elle même; on lave cette argile......." It has been already observed that the main object of these notes is as much to elicit, as to impart, information; and this consideration, combined with the daily progress in the arts of manufacture, forbids the expression here of a final decision as to the absolute merits, or demerits of any particular fire-brick localities or makers, especially as the results of experience, from time to time, can be always communicated to those who may want them. And, though this paper doubtless contains much that is elementary and well known to the majority of our officers, to some perhaps even the elementary principles of the subject are unknown, although its practical application may be of interest to them. For such have these notes been compiled, with the hope that, however imperfect, they will not be altogether useless, and that they may be some day expanded by the researches of inquirers, more competent to the task, and less restricted in opportunity, than the writer, into a thorough investigation of the resistance to fire exercised by refractory materials —a subject of which there is yet much to be learned; one which must be grounded upon a series of most careful experiments; but one which would amply repay the labour of inquiry.

Royal Arsenal, Woolwich,
1st January, 1870.

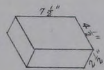
G. E. G.

FIRE-BRICKS FOR FURNACES.

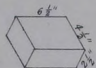
1. 9 inch Brick.



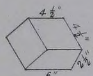
2. Three quarter B.



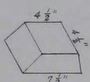
3. Short three-quarter B.



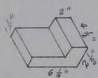
4. Single-bevelled three quarter B.



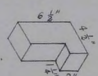
5. Double bevelled three quarter B.



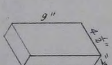
6. Short $\frac{3}{4}$ B. rebated on flat.



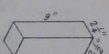
7. Short $\frac{3}{4}$ B. rebated on edge.



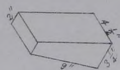
8. Split Brick.



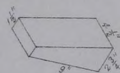
9. Soap Brick.



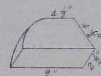
10. Large Bull Head.



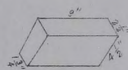
11. Small Bull Head.



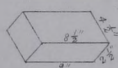
12. Round Corner.



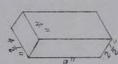
13. Arch Brick.



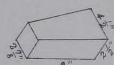
14. Skewback Header.



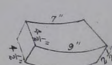
15. Skewback Stretcher.



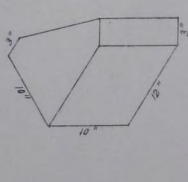
16. Compass Header.



17. Compass Stretcher.

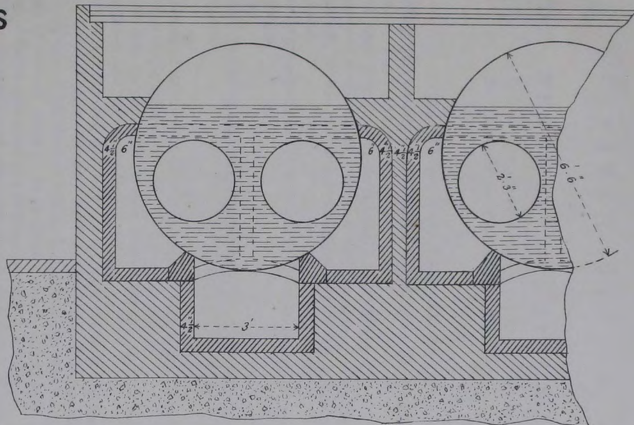


18. Lump for Boiler Seating.



G. E. Grover. Lieut. R.E.

FIRE-BRICK LININGS
TO
BOILER SEATINGS.



Scale $\frac{1}{480}$.

G.E. Grover. Lieut. R.E.

PAPER VI.

ON DEFENSIVE REFORM.

By Captain A. PARNELL, R.E.

(I.)—Preliminary Remarks.

The following propositions are submitted regarding an Engineer's duties in land defence.

In the first place they do not consist merely of fortifying.

The Engineer is, or should be, entrusted with the *defence* of a place.

Defence should be his end, and fortification, one of the means to be used towards this end.

His means lie principally in the application of the following, viz:—

1. Fortification,
2. Artillery,
3. Musketry, (including all kinds of bullet fire)
4. Sorties, and
5. Mines.

The application of any one of these is as much a part of his duty as the application of any of the others.

There is, in fact, no limit but his own knowledge and the materials at his command, to the means he may employ in defence.

Of the means enumerated, Artillery is, obviously, the most effective at present known. Its application should, therefore, be developed to the utmost, and every other instrument, fortification included, should be made subservient to it.

The method of defence about to be proposed consists, accordingly, not of an armed system of fortification, but of a fortified system of Artillery.

As regards the application of musketry, sorties, and mines, these are clearly most valuable branches of defence, and should be made the most of, as circumstances permit.

(II.)—Proposed Method of Defence.

Principles. Artillery, in direct fire, is the basis of the proposed defence.

Fortification is also applied, and the general features of the Polygonal System are adhered to.

The direct artillery of a fortified place, bearing on the attack, must be subdued, if not wholly, at all events, to a very great extent, before the 2nd parallel can be commenced.

In this fact the gist of successful defence appears to lie.

The issue of the siege is practically bound up with the result of the fight between the two artilleries.

The direct fire of the place should, therefore, be developed to the utmost reasonable extent, and should be applied and disposed in the most excellent manner.

Assuming a certain sum of money to be granted by the State for purposes of land defence, the *maximum* reasonable proportion of this should be appropriated to the application of direct artillery, in order that the fire of it may be preserved to the last, and that the greatest damage may be inflicted on the besiegers at the earlier period of attack, when they are at some distance from the place,—in fact, that they may be kept at *arm's length.*

When the direct artillery is silenced, the besiegers *must,* in the ordinary course of things, and in spite of flanks, ravelins, redoubts, and all other outworks and close defence, eventually take the place.

If the direct artillery can be kept unsubdued, the besiegers *may* be kept off altogether.

Now, in order to obtain this maximum of money for expenditure on direct fire, it is proposed to spend a *minimum* on flanking defences, outworks, and on the excrescences of fortification generally.

We will treat, firstly, of this saving on flanks, &c., and afterwards of its expenditure on artillery.

Saving on Flanks, &c.

Ravelins, redoubts of ravelins, couvrefaces, counterguards, redoubts of re-entering places of arms, and in fact, all outworks in fortresses except the glacis, will be abolished. (See Pl. I.)

Ravelins, which are the principal outworks in use, were necessary features of the bastioned systems of fortification ; but, although they appear to have been retained in the polygonal system, they are not essential to it.

The following are their chief disadvantages :—

1.—Their great expense, whereby money is detained from more important objects. The estimated cost of the ravelin shewn in the polygonal system taught at the R. M. A. is £19,478.

2.—Their being open to enfilade fire, and thus inviting destruction to themselves, the guns, gunners, and gun carriages. Attempts to defilade them by means of cavaliers, traverses, and crotchets, only add to the complication and expense.

3.—The fact of their masking to a certain extent the direct fire of the enceinte.

4.—Their causing gunners, musketeers, guns, carriages, ammunition, and stores generally, to be detached from the main defence, *i.e.* that of the enceinte, which thereby loses in proportion.

The following appear to be their chief advantages in polygonal fortresses :—

1.—They bring, *whilst they are tenable,* a fire of artillery and musketry to bear on the attack.

2.—Being more or less thrust out beyond the enceinte, they impede the enemy's approaches when he has arrived near the fortress.

It is submitted that the advantages are completely overborne by the disadvantages, and that ravelins should therefore be disused.

Both in fortresses and detached forts, the fixed masonry caponiers, usually constructed for flanking ditches of works built on polygonal principles, will be abolished, and for them will be substituted small moveable bullet-proof iron-sided carriages (see Pl. II.), which will be recessed behind the face of the escarp *till wanted*, and whose fire will consist principally of clustered bullets or "mitraille." It is considered that these flanking carriages will be much cheaper than the present caponiers, and sufficiently effective when the effects of the breech-loading rifle and mitrailleur used in *direct* fire from the parapet and *mur-des-rondes* against assaulters are taken into account.

There being thus in fortresses no exposed faces of masonry caponiers, the use of masks or couvrefaces is rendered unnecessary.

Expenditure on Artillery, &c. The saving effected by these means, and indeed also by any other means that can be thought of, is to be spent, as already said, on the application of direct artillery.

There may be diversities of opinion as to the best means of carrying out this application, but these are minor considerations compared to the principles themselves. It is however thought best not to bring forward any general principles without at the same time suggesting means for putting them into practice. Hence, the following list of objects is given, to which it is proposed chiefly to devote the expenditure. (See Pl. I.)

1. Very heavy artillery, such as the 8-inch and 9-inch muzzle-loading rifled guns, for the armament.
2. Moncrieff's carriages for mounting the bulk of these guns in protected barbette, so as to obtain the greatest effects from their lateral range, and consequent possible concentration of fire, and the greatest reasonable protection to the guns and gunners.
3. An effective arrangement of the guns on the ramparts.
4. Railways, and fixed steam engines, to move the guns.
5. Artillery parks behind the ramparts, in which parks the guns would be massed, when not required on the terreplein.
6. High, and very thick parapets, for the protection of guns, gunners, gun-carriages, and interior of work generally.
7. As a consequence of the massive parapets, but also as inherently advantageous, unusually deep ditches.
8. An effective profile generally, both as regards security from the besiegers' fire, and from attempts at a *coup-de-main*.
9. Ample bomb-proof cover as follows;

a. Haxo casemates for a certain number of guns on the ramparts, protected in front by iron shields.

b. Grand powder magazines.

c. Expense powder magazines.

d. Bombproof shelter rooms for gunners, on the ramparts.

e. Casemates for the garrison.

f. Covered communications from the casemates to the ramparts above, to the chemin-des-rondes, and to the caponiers.

10. Iron plates to cover the superior slope of the parapet to a certain extent in front of a proportion of the Moncrieff guns.

In the foregoing objects, any, or all, of which might be adopted, according as money was available, it is conceived that there is ample scope for profitable expenditure. Perhaps iron turrets might be advantageously employed in certain cases, or uncovered guns mounted on ordinary traversing platforms, and protected in front by iron shields.

In fact, whatever may at the time be considered as excellent for the effective application of direct artillery, is a legitimate object for defensive expenditure.

Fortification. Pl. I., Figs. 1, 2, 3, 4, and 5.

The proposed fortification hinges on the artillery. For the due application of the latter massive ramparts, big ditches, a high glacis, a broad parapetted chemin-des-rondes, well revetted scarps and counterscarps, an efficient apparatus for bringing a flanking fire to bear, when wanted, along the ditches, and unenfiladeable faces to the ramparts, are all necessary.

As regards the trace, the polygonal principles will be carried out.

Thus the lines of defence will be as long, and the salient angles as obtuse, as possible. As mitrailleurs are efficient at 800 yards, the lines of defence may be, when necessary, of this length; consequently the length of a front of fortification may be 1,600 yards. Every face and front will be unenfiladeable, and there will be no re-entering angles in the trace, except those necessitated by the shape of the ground. The trace of a fort or fortress will be as simple as that of a field redoubt or of a coast battery. (See Pl. I.)

The proposed fortification is merely the disposal of a certain profile in such lines, best suited to the circumstances of the ground, that the place to be defended is covered in the manner most advantageous for the employment of its offensive artillery. There are no sinuosities of any kind in the trace. The reverse batteries, crochets, couvrefaces, ravelins, first flanks, second flanks, orillons, low batteries, wings, &c., of the Antwerp enceinte, which may be taken as a type, in some respects, of the polygonal system, will not be required.

Choumara's device of making the rampart take a course independent of the ditch will be rendered needless. The object he had in view is gained by the immense training the Moncrieff guns are capable of.

The field for ingenuity is limited to the profile, to the arrangement of the artillery, and perhaps to the small flanking carriages; but the latter are not considered as permanent parts of the fortification, and would only be supplied at time of siege.

In detached forts protecting each other, there will be no need of *flanks*, which being enfiladeable, necessitate numerous Haxo-casemates, and are consequently sources of expense. The *faces*, which will be unenfiladeable, will be prolonged sufficiently to mount the necessary armament, and the sides and gorge of the work will be enclosed by ditches and parapet walls, which will be sufficient to resist field artillery, or a coup-de-main. Mutual protection will be afforded by means of the capability of horizontal range possessed by the Moncrieff guns.

Musketry. Musketry fire, including that of breech-loading rifles, mitrailleurs, wall pieces, and one-pounder swivels, is used to the utmost extent in direct fire from the parapets, mur-des-rondes, (*i.e.* parapet of chemin-des-rondes), glacis, and rifle pits in advance, according as circumstances permit during the siege.

The effect of breech-loaders in direct fire will, owing to the rapidity with which it can be sustained, be very great, especially from the mur-des-rondes, when resisting a coup-de-main. The rapidity is 10 times as great as can be effected with muzzle-loading rifles, and these, it must be remembered, were the weapons in the hands of our Infantry, when most of the caponiers of the forts, lately built, or now building in England, were designed.

The effect also of mitrailleurs (weapons not yet introduced into the English service), will, in direct fire against troops advancing in the open, be tremendous In an article from the *Standard* newspaper, quoted with approbation by Major Fosbery, V.C., B. S. Corps, who has been endeavouring to procure the introduction of this arm into the service, the power of one of these weapons is considered equivalent to that of 120 infantry, armed with breech loaders. Mitrailleurs are light and handy, with no recoil, and could probably be mounted on, and fired from, any banquette available for musketry.

With these and breech-loaders combined, acting in direct fire against stormers, there can hardly be any question that the amount of flanking fire which it has hitherto been considered necessary to bring to bear along the ditches, may be materially reduced.

It is partly owing to this that it has been ventured to propose the small caponiers detailed hereafter.

(III.)—Details.

Caponiers, Pl. I Figs. 1, 2, 3, 4, and 5, and Pl. II., Figs. 1, 2, 3, 4, 5, 6, 7. The caponiers are not provided until a time of war likely to necessitate the employment of these works. Sufficient material will be placed in store at a time of expected attack, to provide in fortresses, 4 caponiers, viz., 3 for the fronts attacked or collateral thereto, and 1 in reserve; and in forts the number requisite for flanking the whole of the ditches. The caponiers need not be put together and mounted in recesses behind the escarp until the attack is about to commence. They are disposed according to the length of the ditches to be flanked, either in the centre of the face, or at every alternate salient angle. The former course will be adopted as a rule in fortresses and fronts of fortification, or where the faces exceed 500 yards in length, and the latter would be the rule in forts.

In fortresses, the fronts not attacked will depend on their direct fire for resistance to a *coup de main*. The parapets, mur des rondes, and glacis of these fronts will, owing to their not having been assailed by the besieger's artillery, be in a comparatively perfect state when attacked by escaladers.

These would meet with the following resistance, viz. :—Shrapnel and case shot from the heavy guns, with bullets from mitrailleurs and breech-loaders from the ramparts, until they reached the crest of the glacis, when they would come under the fire of the mitrailleurs and breech-loaders posted behind the mur-des-rondes.

As regards the proposal not to supply caponiers until time of war, it is suggested that before the fort or fortress is employed, the effect of direct fire may so increase, owing to improvements in the arms in use, that flanks may be rendered needless altogether; or if needed, temporary ones, hastily thrown up in the ditch, may be found to answer every purpose. Leaving out the caponiers at the time of the fort's construction may thus be a great advantage, and the form of moving caponiers proposed in this paper need not necessarily be adopted. The question of the best form to be eventually given may be digested at leisure.

The caponier proposed consists of a long low rectangular box, with the rear end open, and mounted on small flanged iron wheels, which run on iron rails. The box or carriage is formed of two long girders supporting a wooden framework, to which are bolted the iron plates constituting the roof, front end, and two sides. The bottom or floor is made of 2-inch planking, laid on joists framed into the girders. The plates are $\frac{3}{8}$-inch boiler plate iron, which appears to be bullet proof. The sides are pierced by musket holes 3 inches in diameter, and by mitrailleur holes 12 inches in diameter. The caponier is, when not required for use, drawn up in an arched bomb-proof recess, formed behind the escarp wall. In this position the only exposed portion of the caponier is the front end. It is completely protected from fire along the length of the ditch. It is run out or drawn back (the latter being done at leisure) by means of a certain number of men hauling on tackle. To facilitate the running out, which might require to be done quickly, the rails on which the carriage runs are given an inclination downwards of 1 in 50.

When recessed, the mitrailleurs forming the armament are kept in it, with a certain amount of ammunition, all in readiness for immediate use. The lower tier of loop-holes is formed en machicoulis, by simply projecting the upper portions of the sides of the carriage, which is thus rendered self-defensive. The roof, part of the sides, and the main ditch in front, are commanded by musketry from a small loop-holed gallery built above the recess. Musketry is also directed from the recess along the roof and sides, and under the floor of the carriage,—also from the *mur-des-rondes*, on the roof and sides, and adjacent main ditch. The recess and the gallery leading thereto from the interior form a postern, available for sorties, and the caponier acts as a gate. It can be run out 4 feet beyond the face of the escarp when necessary to facilitate the passage of troops. The carriage is placed, when run out, in a drop ditch 7 feet below the main ditch. This secures the mitrailleur-holes from being made use of by assaulters.

The construction of the caponier is intended to be as slight and cheap as possible, consistently with efficiency in time of need. It should be easily put together, taken to pieces, or repaired.

The exact shape of the carriages for the mitrailleurs is not shewn. They would, however, be very light and handy, the mitrailleurs themselves being light, and having no recoil. The rails and their bearers would be laid so as to be easily repaired, if injured by the enemy's vertical fire.

The caponier now under consideration, and shewn in Pl. II., is the model proposed for all ordinary forts. It is pierced on each side for 4 mitrailleurs and 30 breech-loaders. The weight of it, exclusive of mitrailleurs, is estimated at 9 tons 13 cwt., and including them, at 11 tons 5 cwt.

The caponier in a maximum form, as proposed for fortresses having very long ditches, is shewn in elevation in Pl. I, fig. 4. It is 2 storied, and carries, on each side, 12 mitrailleurs and 90 breech-loaders. Any form can, however, be adopted which might be thought most suitable to the particular work. The ends of the posterns, or recesses, in which, in fortresses, caponiers were not mounted at the time of attack, would be closed by strong gates.

From a careful detailed estimate, based, so far as practicable, on the Chatham District Schedule for 1869, the final expense of the caponier, shewn in Pl. II, including excavation for site and disposal, arched recess, loopholed gallery, railway, and all accessories, with $\frac{1}{10}$th added for contingencies, would amount to £600, of which only £270 would constitute the *first* cost, that being the estimated value of the recess, gallery, excavation, and everything except carriage and railway, which (costing together £330) would not be provided until the fortification was attacked.

The advantages claimed for these moving caponiers, are as follows:—

1. Their great cheapness as compared with the usual style of caponiers in English forts. The expense of one of these caponiers, average sized, 2 storied, double faced, built of masonry, covered with bomb-proof brick arches, mounting 4 guns on each side, with flanking galleries, expense magazine, passage in rear (to the same extent as the arched recess for a moving caponier), excavation and disposal for site, extra excavation and disposal necessitated by the increased width of ditch round the head of caponier, and all other contingencies, is probably not less than £4,000. Thus the estimated saving at first is £3,730, and this is also the estimated eventual saving if the fort is never used; whilst £3,400 is the estimated saving if the fort is attacked. Allowing, in an ordinary fort, that there are caponiers, (double or single) and flanks, together equivalent to 3½ double caponiers, which seems a not unreasonable assumption, it is estimated that there will be a possible saving of £13,055, and a certain one of £11,900, on the whole fort, neither of which sums are by any means inconsiderable proportions of the value of ordinary forts.

2. The caponier is in such a form that it need not be provided and put together till it is wanted. This is an advantage, when the rapidity with which all things used in war become obsolete is taken into account, for an obsolete thing, when the time of action arrives, may be not only useless, but worse than useless.

3. They can be placed in ditches in the most convenient positions for flanking

them, without reference to the prolongation of the ditches being taken up by the enemy's artillery.

4. Their liability to injury, from the enemy's fire, whether the latter be distant, or from the edge of the counterscarp, is far less, owing to their comparative lowness, and to their being recessed behind the escarp, except when wanted for use.

5. Their facilities for repairs are greater. New wood-work, or new plates, can easily be fixed.

6. Their facilities for the fire of breech-loading musketry are greater, on account of the thinness of their sides, and the number and smallness of the loopholes.

7. Their immunity from injury by mining is greater.

The following appear their chief disadvantages:—

1. The inconvenience (though only temporary) of shutting up a number of soldiers in a comparatively small iron box, against which the effect of many bullets striking at once would be very annoying.

2. The loss of bombproof cover, occasioned by not adopting the usual roomy arched caponiers.

3. The possibility of the mitraille and musketry not being sufficiently effective to stop escaladers,

4. The possibility of the stormers of a breach being masked by the debris of it from the fire of the carriages, they being so low.

5. War may be so suddenly declared, and an attack on the work so quickly made, that the place may be taken by coup-de-main before there has been time afforded to supply it with caponiers.

The proposed caponier is as applicable to a *wet* ditch as to a dry one. In the former case it would float, both in ditch and recess, the bottom being formed of water-tight iron plating.

The idea of these carriages first occurred to me in 1867, after reading Sir John Burgoyne's note, in Corps Papers, Vol. XIII. "On the Bridges of Fortified Works." Sir John therein suggests a fixed bridge "of masonry with vertical sides, loopholed, and acting as a caponier." The connection thus made between a moving bridge and a caponier, originated the idea of a moving caponier. An attempt to work out a project for such a caponier was frustrated by the difficulties which appeared to be attendant on the *weight* and *recoil* of the *guns* which were considered necessary for the armament. On the appearance, however, of Major Fosbery's interesting paper on mitrailleurs, in Vol. XIII. of the "United Service Journal," (1870), the idea presented itself in a more feasible light; hence the introduction of it in the present paper. It seems, however, not impossible that these moveable caponiers might be constructed to carry guns, if the latter are deemed essential.

It may also be noticed here with reference to Sir John Burgoyne's note, above quoted, that one of the caponiers made sufficiently high and of the requisite strength, might possibly be useful as a moving *bridge* to a fortress.

Mitrailleurs. Pl. II. Fig. 2. Some description will now be given of the Mitrailleurs, several times mentioned previously in this paper. The best *known* one in use, in America, or on the Continent, appears to be the "Montigny."

The following details concerning it are condensed from Major Fosbery's published accounts. It consists of 37 steel barrels, with Metford rifling, and enclosed in a wrought-iron tube. It is provided with vertical and horizontal adjustments, has no recoil, and ranges to 1,000 yards. The calibre of each barrel is ·534 inch; the bullet is hardened, weighing 600 grains, and can penetrate at 60 yards, without much deformation, 29 half-inch dry elm planks. The charge is 115 grains, but might be advantageously 125 or 130 grains. The cartridge is by Fusnot, of Cureghem, near Brussels; but it carries the Boxer cartridge admirably. It is fired by a man revolving a handle at the breech, by which revolution the whole of the 37 barrels can be discharged in one second. Each barrel can be fired separately, or at any interval of time. The piece can be discharged 12 times in a minute, thus throwing 444 bullets in that time. The single discharge of 37 bullets covers a space of about 10 feet by 12 feet. at 800 yards, at which range the elevation is 2° 5′. It can be modified to allow of the fire of a single discharge being distributed through a larger horizontal area than that due to the natural cone of dispersion. Three marksmen from the infantry suffice for its management. It weighs about 400 lbs. A piece on the same principle could be constructed by Major Fosbery, excelling it both in range and efficiency.*

Saving on caponiers and outworks. In estimating the saving effected in fortresses, or fronts of fortification, by using these moving caponiers, not only the cost of the fixed caponiers must be taken into account, but also that of the usual "couvreface" or "mask" appertaining thereto. The estimated cost of the caponier (in its maximum form) shewn in figs. 2 and 4, Pl. I, as applied to a front of a fortress, is £1,800, of which £810, the value of the recess, gallery, &c., would be the first cost.

The estimated cost of the caponier and mask shewn in the front of the polygonal system taught at the Royal Military Academy is £28,330. There is thus an estimated certain saving on the flanks of £26,530, and an estimated possible saving (realised should the front never be attacked) of £27,520. If to each of these sums the estimated cost of the abolished ravelin, *i.e.* £19,478 (as already mentioned) is added, the saving per front becomes £46,008 or £46,998.

Taking into account the cost of the two redoubts of re-entering places of arms, the two flanks to the ditches of the ravelin, and the sinuosities of the trace of the enceinte, all as shewn in the front taught at the Royal Military Academy, and all of which are abolished, the certain saving per front, if the above estimates are tolerably correct, cannot be put down at less than £50,000.

Defensive expenditure. It is obviously good economy in defensive expenditure to provide in time of peace, or *before* they are wanted, only such works and *matériel* as cannot be provided in time of war, or *when* they are wanted.

There is hardly any doubt that the fact of the existence of permanent fortifications, though unarmed and unfurnished, tends *against* their employment, and

* Since writing the above, the Montigny mitrailleur has been tried at Shoeburyness.

that a comparatively very small proportion of forts or fortresses, (which it may be, however, very sound policy to build) are actually ever engaged.

Again, when they are actually required for use, perhaps a long time after their construction, the art of war will probably have undergone great changes, and what may have originally been considered most formidable, will, owing to these changes, have become harmless. For these reasons there is much in permanent fortifications which need not be provided till war is declared, and an attack imminent.

The following list shews the personnel, matériel, and works, which it is considered may be thus treated :—

1. The garrison.
2. The armament.
3. The ammunition, and artillery matériel.
4. The arrangement of the ramparts to receive the armament, including the provision of Haxo casemates and iron plates.
5. The railways and engines.
6. The mitrailleurs, spare breech-loaders, wall pieces, one-pounder swivels, spare bayonets, and small arms generally, with all necessary ammunition.
7. The caponiers.
8. The mur-des-rondes.
9. The stores, tools, and materials for the engineer park.
10. The interior fittings to the casemates, and to the bombproofs generally.
11. The commissariat and transport supplies, also the barrack and military stores.

Garrison.

The number of the garrison will be based upon the number of *heavy guns*. The proportion will be 30 men per heavy gun. They will be divided into three reliefs, thus giving 10 men per gun per relief. As a rule, however, not more than two-thirds of the heavy guns will be required for use at the same time. There will thus be at the commencement of a siege 15 men per gun in use, per relief. Of these, 10 will be wanted for the service of the gun, and the other five (or one-third of the relief) will be engaged in the other necessary duties connected with defence, for instance in the following, viz.

1. Shifting guns on the railways.
2. Attending artillery park and stores.
3. Attending powder magazines.
4. Keeping up musketry fire (including mitraille, &c.) from various portions of the work.
5. Guards to mur-des-rondes, caponiers, quarters, &c.
6. At work in engineer park, or carrying out defensive arrangements, works and repairs, under the engineers.
7. Fatigues, cook's mates, &c.

The relief next for duty will be always ready to turn out at a moment's notice. They will be wanted on special occasions, such as when all heavy guns are needed to be served at the same time, or when an attempt to escalade has to be repulsed. The relief last on duty will have absolute rest for 8 hours, unless extremely urgent circumstances require their attendance.

By the above arrangements, two-thirds of the men, one-third of the heavy guns, and one-third of the emplacements for the latter, are as a rule in reserve. There will be a great advantage in having fresh guns to fall back upon from time to time, also in being able to shift the guns to new emplacements, the parapets of which will be comparatively intact.

The rules laid down will be adhered to with more or less strictness throughout the siege, according to the relative rates at which men and guns become disabled. The garrison will be composed thus:—

Artillery—4 out of every 10 men per gun, or $\frac{2}{5}$ of garrison.
Engineers .... $\frac{1}{25}$,,
Infantry .... $\frac{14}{25}$,,

Applying the foregoing rules to the fort, shewn in Pl. I, fig. 1, the garrison will be 24 × 30 = 720 men, composed as follows:—

Artillery	288
Engineers	29
Infantry	403
Total	720

For the front of fortress shewn in Pl. I, fig. 2; the garrison will be 120 × 30 = 3,600, composed thus:—

Artillery	1440
Engineers	144
Infantry	2016
Total	3600

The artillery should be trained to engineer and infantry duties, the engineers to those of artillery and infantry, and the infantry to those of artillery and engineers. Thus every man will be comparatively handy for any work he may be called on to do. Great advantage will ensue if every man is an artificer, or accustomed to labour on works.

Armament. There appears no doubt that the 7-inch breech-loading gun of 72 cwt. or 82 cwt., throwing 90 lb. shells, will form part of the equipment of future siege trains.

This fact necessitates the use of the 7-inch 7-ton muzzle-loading gun, throwing a 115 lb. shell, as the minimum weight for the heavy guns of the fortress or fort. Since, however, it is intended to apply to the heavy guns a regular system of railways, by means of which they may be moved with comparative ease, it is considered that a still heavier gun than that weighing 7 tons, may be used with advantage for the bulk of the armament, and one that will carry a more decided advantage over the 7-inch breech-loading gun of the besiegers.

The 8-inch 9-ton muzzle-loading gun, which throws a 180 lb. shell, will therefore constitute the main portion of the armament. It will be mounted on the Moncrieff principle, for there can be no doubt that Moncrieff's carriage will serve this gun equally well as the 7-ton one.

In the shielded Haxo casemates, advantage will be taken of their great security to the utmost, and the guns mounted in them will be 9-inch 12-ton muzzle-loading, which throw shells weighing 250 lbs.

The armament will be composed as follows:—Three-fourths of the whole number of pieces will be *heavy* guns; (the number of these, as already stated, is the basis of the number of the garrison); $\frac{9}{10}$ of these guns, or $\frac{27}{40}$ of the whole, are 8-inch 9-ton muzzle-loading, mounted en barbette à la Moncrieff; the other $\frac{1}{10}$ or $\frac{3}{40}$ of the whole, consist of 9-inch 12-ton muzzle-loading, mounted on traversing platforms in shielded Haxo casemates.

The remaining $\frac{1}{4}$ of the whole number of pieces is divided thus:—One-half, or $\frac{1}{8}$ of the whole, are 40-pr. breech-loading, mounted on siege or travelling carriages; $\frac{1}{4}$, or $\frac{1}{16}$ of whole, are 12-pr. breech-loading, on field gun carriages; and $\frac{1}{4}$ or $\frac{1}{16}$ of whole, are 10-inch mortars.

The number of the heavy guns in a work is based on its size.

The rule will be as follows, whether in forts or fortresses:—The number of heavy guns should equal $\frac{1}{40}$ of the combined length in feet of the three longest adjacent fronts or faces likely to receive attack. The heavy guns can thus be massed on these fronts, at 40 feet central intervals; but, as before observed, only two-thirds of them would probably be mounted at one time.

The armament for the front of fortification shewn in Pl. I, fig. 2, would be as follows:—

Number of heavy guns		$= \frac{1}{40} \times 4800$	$= 120$	
"	9-inch guns	$= \frac{120}{10}$	$= 12$	120
"	8-inch guns	$= \frac{9}{10} \times 120$	$= 108$	
"	40 prs.	$= \frac{160}{8}$	$= 20$	40 (or $\frac{120}{3}$)
"	12 prs.	$= \frac{160}{16}$	$= 10$	
"	10-inch mortars	$= \frac{160}{16}$	$= 10$	
		Total	160	

For the fort shewn in Pl. I, fig. 1, it would be thus:—

Number of heavy guns		$= \frac{960}{40}$	$= 24$	
"	9-inch guns		1	.. (at salient)
"	8-inch guns		23	
"	40 prs.	$= \frac{1}{8} \cdot \frac{24 \times 4}{3}$	$= 4$	8 " "
"	12 prs.		2	
"	10-inch mortars		2	
			32	

The 40 prs., 12 prs., and 10-inch mortars are provided, not necessarily for employment, but because circumstances *might* arise rendering their use beneficial. They may be considered more as supplementary, than as essential, to the armament. The 40 prs. will be useful in relieving occasionally the heavy guns, but would come into employment, as a rule, only at a late period of the siege, when a great many heavy guns would possibly be disabled. The 40 prs. would be fired either on ordinary barbettes, or through iron-shielded embrasures.

Ammunition. The number of rounds of ammunition furnished will be as follows:

In forts	for heavy guns	300	rounds per gun.
	for supplementary pieces,	75	„ „ piece.
In fortresses,	for heavy guns	400	rounds per gun,
	and for supplementary pieces,	100	„ „ piece.

The projectiles will be proportioned thus :—

Heavy guns....	$\frac{7}{10}$ common shells	= 210	rounds.
	$\frac{2}{10}$ Shrapnel shells	= 60	„
	$\frac{1}{10}$ case shot	= 30	„
	Total	300	
40 prs. and 12 prs.	$\frac{7}{10}$ common shells	= 52	rounds.
	$\frac{2}{10}$ segment shells	= 15	„
	$\frac{1}{10}$ case shot	= 8	„
	Total	75	„

10-inch mortars,—all common shells .... 75 rounds.

The amount of gunpowder provided is based on the number of rounds required for the heavy guns, and somewhat exceeds a proportion of 30 lbs. per round. This, taking into account the different kinds of heavy guns, charges, and projectiles, is about the average amount that, including bursting charges, would be expended per round. There is one expense magazine holding 100 barrels, or 10,000 lbs., to every two guns, which are thus each supplied with 167 rounds. A grand magazine, containing 1,000 barrels, or 100,000 lbs., is provided for every 24 guns in forts, and for about every 13 in fortresses, in the former case affording 133 rounds, and in the latter case, 233 rounds, per gun, which make up the respective complements of 300 and 400 rounds.

No extra provision of powder is made for the service of the supplementary armament.

Applying the above arrangements to the 24-gun fort shewn in Pl. I, fig. 1, the ammunition will be as follows :—

Heavy	1 9-inch gun	250-lb. common shells	210	300
		250-lb. shrapnel do.............	60	
		100-lb. case shot	30	
	23 8-inch guns	180-lb. common shells..........	4830	6900
		174-lb. shrapnel do......... ...	1380	
		68-lb. case shot	690	

Supplementary	4 40-prs.	40-lb. common shells..........	208	300
		40-lb. segment do.............	60	
		31-lb. case shot	32	
	2 12-prs.	12-lb. common shells	104	150
		11-lb. segment do.............	30	
		9-lb. case shot	16	
	2 10-in. mortrs.	Common shells		150

	lbs. of powder.
12 expense magazines at 100 barrels, or 10,000 lbs.....................	120,000
1 grand magazine at 1,000 barrels, or 100,000 lbs.	100,000
Total....	220,000

The above gives an average charge per round for heavy guns of $30\frac{5}{9}$ lbs.

As it is proposed not to employ in forts or fortresses, as a rule, more than two-thirds of the heavy guns at the same time, the number of rounds afforded *per heavy gun in use* will be in forts 450, and in fortresses 533.

Artillery arrangements. Pl. I, figs. 1, 2, 3, 4, 5, 6, 7, 8.

It will be seen that the proposed application of the Artillery is mainly based upon Captain Moncrieff's magnificent invention. This is now adopted into the service, and the present scheme is one intended to utilize it to the utmost. If any other system of mounting guns, based on the protected barbette principle, be hereafter introduced, there will probably be no difficulty in applying to it the details proposed in this paper for Moncrieff's carriages.

It is not proposed that any of the guns should be mounted on the ramparts, nor provision made for their being mounted, until war should be declared, and an attack on the work imminent. The employment of Moncrieff's guns for the bulk of the armament of land forts, with Haxos at intervals, is the principle already laid down by the authorities for adoption in England.

The arrangement of the Moncrieff guns with their attendant magazines, shelter rooms, turn-tables, and railways, shewn on Pl. I, fig. 3, is that which is proposed for adoption in all attacked fronts or faces and of fortifications generally. The guns, mounted on their Moncrieff carriages, rest on turn-tables, formed of pairs of parallel girders pivoted at the centre, and traversing by means of small wheels on circular racers. Each turn-table is connected with a line of railway, by means of which the gun can be readily removed, it being presumed that the counterpoises of the Moncrieff carriages can be detached and left behind, and afterwards attached, if necessary, to a new gun and carriage.*

* The counterpoises might probably be made to work in the casemates beneath the terreplein, and, if so, might be of such a nature that they could readily be detached from the guns, and would moreover not require to be constructed till the guns were mounted.

The turn-tables are disposed in semi-circular recesses, 20 ft. in diameter, cut in the parapet at 40 ft. central intervals. There is thus a splinter proof traverse 20 feet wide between every pair of guns. For every two guns thus paired, there is provided, under the parapet, a bomb-proof shelter room for the gunners and for side-arms, &c.

Underneath this shelter room, to which communication is afforded by a manhole (provided with a ladder and forming also a lift) is an expense magazine holding 100 barrels. This magazine is entered from the passage running along the back of the men's casemates. Covered access is thus given from the latter to the guns above. This arrangement is on the system devised by the late Colonel Owen, C.B., R.E.

The Haxo casemates are disposed in fortresses at the rate of 1 to every 10 Moncrieffs, and in forts, each shoulder or salient would be occupied by a Haxo.

The training of each Moncrieff gun, under ordinary circumstances, and when disposed as above-mentioned, is 120°. But, in case of necessity, they can each be trained the whole circle, or 360°. When the adjacent emplacements are unoccupied, a training of more than 120° can, wi hout difficulty, be effected. In forts, the power of firing to the rear on the gorges, or on the adjacent ground, might occasionally be of great use.

When the besieger has decided on the front, or fronts, of a fortress he intends to attack, this front and the two collateral ones, (or in the case of *two* fronts being attacked, these, and half of each of those collateral), will be placed in a state of action by cutting out the recesses from the parapet and revetting them, laying the racer curbs and racers, building the Haxos, fixing the iron-plates and shields, and opening and fitting up the shelter rooms and magazines. In the case of forts, this would be done on those faces, 3 at the outside, which could at all bear on the enemy's attack. The revetments, racer walls, and Haxos will be built of rough brickwork set in Roman (or other cheap quick setting) cement, by the Engineers and garrison generally. But little plant will be required, and the work will be rapidly done. A supply of bricks, cement, and iron racers will be placed in store at the time of the expected attack, and in sufficient abundance to allow of a large reserve for use in repairs during the siege. Oak racer curbs will also be kept in store to be used when necessary.

The above arrangements are based on the supposition that underneath the ramparts in question there are casemates, the roofs of which will form convenient foundations. But if it were necessary to prepare for action ramparts under which no casemates had been built, which would probably only be the case with faces or fronts little likely to be attacked,—whence the contingency in question would be little likely to happen,—the revetments, racers, and Haxos would be built on rough rubble foundations, carried up, when the work was first constructed, to the level of the terreplein. On fronts, or faces, not likely to be attacked, revetments and racer foundations would be carried up, in pairs, at intervals of 160 feet from centre to centre of pair, in lieu of 80 feet, as on exposed fronts.

On the superior slope of the parapets in front of $\frac{1}{3}$rd (or every third pair) of the Moncrieff guns on the front, or face, or two half-fronts, or half-faces, most exposed, will be fixed 4-inch iron plates (as shewn in Pl. I, fig. 8.) Iron shields, built up to the requisite thickness, will be fixed in front of the Haxo casemates.

The expense magazines and bombproof shelter rooms are built when the work is first constructed. They are *unearthed*, (their entrance being cleared) and fitted up, when the adjacent recesses are cut. They are only carried up at 160 feet intervals, in fronts not likely to be attacked. It would be impossible to build the magazines, and difficult and undesirable to build the bombproof shelters at time of attack. It will be seen that earth for covering the Haxos, forming banquettes, repairing parapets, &c., is obtained from the cuttings for the recesses.

As regards building the parapet revetments of brick, it is suggested that, although the time of building will be longer, yet the greatest interior space is hereby obtained, and the revetments are stronger, and last longer, than the usual temporary ones. These brick revetments, and the brickwork generally, would be repaired from time to time, during a siege, by means of the bricks and cement in store.

If, in a fort, it should happen, under exceptional circumstances, that there were enfiladeable faces, and that it was desirable to mount guns on them, the latter would be spaced at 60 feet central intervals, thus allowing a traverse 40 feet thick between every pair.

Concentration of Artillery fire Pl. I., fig. 9.

The power of *concentration* of fire afforded to the heavy guns by the proposed dispositions will be very great.

The following table shews the number of guns the fire of which can be converged on any given point in lines drawn parallel to the front of a fortress, at the distance named, the results being taken from the diagram given in Pl. I. Fig. 9, in which are represented the outlines of three adjacent fronts, each 1600 yards long, and each inclined to its neighbour at 160°, an arrangement also shewn in Pl. 1, fig. 2. The extreme lateral range of each Moncrieff is taken at 120°, and that of the Haxos at 70°.

TABLE OF CONCENTRATION.

Distance of line from front.	Number of Guns whose fire can be concentrated on any point in line.						
	9-inch Haxos.		8-inch Moncrieff.		Average No. of Haxos (250 lb. shells.)	Average No. of Moncrieff's (180 lb. shells.)	Average number of heavy Guns.
	at Centre.	at Capital.	at Centre.	at Capital.			
yards. 610	7	4	108	129	5	118	123
1010	12	7	108	216	9	162	171
1570	12	13	216	216	12	216	228
2000	12	15	294	216	13	255	268
2400	12	19	324	216	15	270	285

It may not be possible to crush the besiegers' batteries before they can be armed, nevertheless the concentration of 180lb. shells, with their heavy bursting charges, in and about the positions of these batteries, the range being, or soon becoming, well known, will make their construction exceedingly warm work. Whilst on the subject of range, it must be borne in mind that the defenders would, or should, know the precise distance from the work of every fence, hedge, tree, mound, land-mark, and object of whatever description, whether visible or invisible from the ramparts, as well as the exact configuration of the ground, within range of their guns.

Railways and Parks. Plate I, figs. 3 and 8.

The railways are laid, at time of attack, on the fronts to be armed. They consist of light rails on wooden sleepers, the whole being laid in a temporary manner, but with sufficient solidity for the required purpose. The gauge is 5 feet, and the radius of the curve branching to each gun from the main line is 75 feet.

The ramps are at a slope of 1 in 15, and 14 feet wide, so as to allow of a double line being laid on them; they are disposed in forts at the rate of 1 per face, and in fortresses at about 1 to 170 yards of front. The ramps are disposed so as to lead the railways, by the most convenient routes, from the terreplein to the park.

This park consists merely of a double line of railway laid parallel to and in front of the casemates, by which it is to a great extent protected. There will only be one park in a fort, and it will be situated in rear of the most exposed face. In fortresses there will be one or more parks to each front. During the siege the parks will, if necessary, be covered from vertical fire by timber blindages. All the heavy guns not in active use on the ramparts will be massed in the park. Those on the ramparts will also be withdrawn thereto, whenever too hard pressed by the besiegers' fire. Some of the casemates will be appropriated as artillery stores and sheds; thus the guns and gunners, with their gear, will be all brought together. Low waggons, or trucks, will be employed to bring up ammunition, &c., on the railways. Rails will be laid from the ramps and park to the grand magazine, and to any other important part of the work.

It is proposed to haul the guns, &c., up the railways by means of steam engines fixed in such casemates as may be conveniently situated for the purpose. In a fort there would be two steam engines, one being in reserve. In fortresses there might be one to each park. Ropes, or chains, led through leading blocks wherever necessary, would be employed in connection with the engines. The latter would, when required, be supplemented by men, horses, and capstans. By means of the railways, the guns can at pleasure be moved to, or from, any emplacement on the terreplein of the fronts armed. They can be massed, or reserved, to any extent, and disabled guns can be rapidly withdrawn and replaced.

As regards the use of railways in fortifications, I may mention that the idea first occurred to me in the latter part of 1866, when employed at Fort Scoveston (Pembroke), which was then being built. At this time I had not heard of Captain Moncrieff's invention. A few rough notes on the proposed use of railways were laid at the time before the Commanding Royal Engineer, at Pembroke. [They were intended to be in connection with guns mounted on a system of protected barbette, somewhat similar to that proposed by Captain Hogg, R.E., in Vol. XVI. of the Royal Engineer Papers.]

Profile. Pl. I., fig. 4, 5.

The chief novelties in the profile are the unusual thickness of parapet and depth of ditch.

For fortresses, on fronts likely to be attacked, the width of the parapet opposite the centre of the turn-table is 50 ft., and the original width before it is recessed, or that at traverses, is 64 feet; but on fronts, not much exposed to attack, these widths are respectively 30 ft. and 44 ft. In forts, on faces exposed to attack, the above widths are respectively 40 ft. and 54 ft.; and on other faces, 30 ft. and 44 ft. The exterior slope is, in all cases, 3 by 4, and the inner slope of traverses (or of parapet when not armed) is 1 by 1. The depth of the ditch in fortresses is 50 ft., and in forts 40 ft. The thickness of escarp and counterscarp walls, if required, will depend of course on their height aud the nature of the ground. Fortresses will have covered ways, but not forts. From the latter, sorties would not so frequently take place, and by omitting the covered way, greater cover is given to the scarp wall, and greater height to the counterscarp. The superior slopes of the parapet and glacis are in the same line, and have an inclination of 1 in 10.

Musketry.

A chemin-des-rondes is in all cases provided. The advantages of these are well known. The chemin-des-rondes parapet wall, or mur-des-rondes, and its banquette, are not built till a time of imminent attack. The wall is 8 ft. high, and formed of 18 inch brickwork, built roughly and as rapidly as possible, in cement, from the materials already mentioned as provided for the revetments and racers. It will be built as far as possible *before* the enemy decides on the fronts or faces to be attacked, consequently before the revetting, &c., for the arming takes place.

The thickness of 18 inches is given for the following reasons:—

1. Economy.

2. The liability of the wall to be smashed on fronts attacked, and the facility afforded for repairs.

3. The power given to a musketeer to lean over and command the foot of the escarp.

The wall would be repaired in brickwork during the siege, so far as practicable; but there would never be much difficulty in making the breached portions musket proof at a time of expected attack, by means of such temporary materials as were handy, such as sand bags, earth, fascines, gabions, timber, &c. The banquette may be formed either of earth, old casks, and barrels, planking on brick piers, brickwork, sandbags, or any other available material.

It will be seen by what has already been said, that great dependence is laid upon the effect of the musketry, including mitraille, which is capable of being directed from behind the mur-des-rondes on stormers. Arched galleries are built under the ramparts from the casemates to the chemin-des-rondes, in order quickly and securely to concentrate troops thereon. In forts there will be one of these galleries to each face, and in fortresses, one to every 200 yards of front.

Banquettes for musketry, will, at the time of the attack, be erected of planks, or in any other convenient manner, along the interior revetments, including both gun recesses and interior slopes of the parapet, on all faces or fronts. At the same time, banquettes will in fortresses be formed, so far as needed, on the interior slope of the glacis.

Bombproofs. Pl. I. fig. 4,5,7. Casemates sufficient to accommodate the whole of the garrison, will be built under the ramparts of the fronts of a fortress, and of the front faces of a fort, when the work is first constructed. No defensible barracks, in rear of the fronts, will be provided in fortresses, or keeps, or interior casemated redoubts in forts.

By the proposed arrangement a great saving is effected, the men are kept close to their guns, and their barracks are less exposed to the enemy's fire. Again, a masonry keep would not be of much use for defensive purposes after the fort had sustained a siege of ordinary duration. Earthen entrenchments thrown up during the siege, would probably answer every purpose of reserved defence, whether in forts or fortresses. The casemates, magazines, both grand and expense, shelter rooms, and bombproofs generally, will be merely bare vaults when first constructed. No doors, windows, floors, fire-places, or fittings of any kind, will be provided until the time of attack. They will then be furnished in the roughest and cheapest manner consistent with efficiency and comfort. There will be no difficulty in temporarily fitting up any casemates that may occasionally be wanted as barracks, or for other purposes, during time of peace.

In time of attack a certain portion in rear of each of the two casemates nearest an expense magazine will be partitioned off by a brick wall, and formed either into a *shell store*, or into a *shell filling room.*

The masonry of the bombproofs and of the work generally, as first constructed, will be of the roughest and cheapest description consistent with efficiency. No money will be spent on anything connected with *appearance.*

The foregoing proposals regarding bombproofs will tend to much saving of money at the time the work is built.

In a fort there will be usually only one grand magazine, which will be built underground, in the most secure and central place, and a covered communication from the magazine to the casemates will be formed by means of an underground gallery. In fortresses the grand magazines will be disposed as above, and will be placed centrally in rear of the guns served by them respectively.

(IV.)—Conclusion.

Artillery, both in personnel and materiel, has always been one of our strong national points, and there is something in a system of direct fire that appeals to the understanding and sympathies of Englishmen generally, and of English soldiers in particular. Although the direct fire of artillery has been thrown into the shade for a considerable time by ingenious systems of fortification, there is hardly any doubt that now—thanks chiefly to Moncrieff, than whom no engineer has done more for land defence since artillery was invented—it is attaining the position that, as the very life and soul of all defence, it is entitled to.

The fortification of the English dockyards and naval ports is now virtually completed, so far as desirable in time of peace; nevertheless the principles suggested in this paper may be of service in the future, and especially if the question of the closer defence of London be revived.

I wish particularly to observe that by no means all the suggestions contained in the foregoing paper are set forward as novelties. I have endeavoured to include in it everything that I could find in existing systems of fortification and defence, and in published ideas thereon, that appeared to be excellent. Some of the opinions and suggestions may also seem to be rather dogmatic. This semblance arises chiefly from a desire to be brief. It would have made the paper tediously long if all the passages in the published opinions of officers of distinction, which have been instrumental in guiding me, had been quoted. The suggestions are given more with a view to discussion and ventilation than with any fixed idea as to their correctness.

Even if all the opinions submitted in this paper should be found to be fallacious, yet, if their publication should elicit the truth on the subjects treated of, I submit that much will be gained.

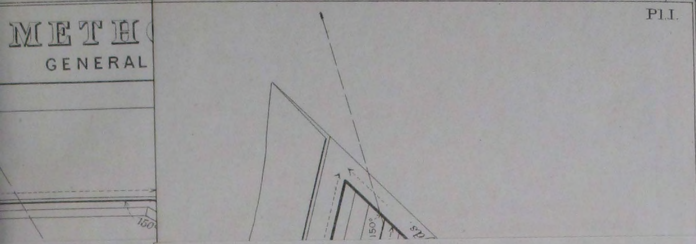
Chatham, 4th June, 1870. A. P.

The Report of the Discussion on this Paper will be found at the end of the Volume.

Pl.I.

METH

GENERAL



PAPER VII.

NOTES ON THE NATURE OF CLAY.

By Lieut. A. B. McHARDY, R.E.

Clay is met with so often in the course of engineering operations, that to understand properly the manner of dealing with it, is a matter of considerable importance. It would, therefore, appear that any thing that can be done to extend the knowledge of the nature of clay, is not altogether useless. The more so, that the extensive slips and failures, which so often occur, seem to point to the fact that the nature of the substance is not fully realized.

The following remarks are brought forward, not with the intention of pointing out anything which is new to those who have had to do with excavations in clay soils, but rather in order to narrate some observations made while superintending excavations in clay, during a period of five years in the Isle of Wight. The facts observed were new to the writer, and have not apparently, as yet, been appreciated, as to their extent, by some eminent geologists.

As is well known, the northern half of the Isle of Wight is composed of tertiary clays, which sometimes alternate with beds of limestone. The beds of deposition of these clays are more or less inclined to the horizon. The lines of stratification are, as a rule, well marked by the different colours of the clay; the prevailing colours being blue and red. This clay is compact, greasy, and, when there is a mixture of shelly limestone, very hard, but generally it is cut by the spade with considerable ease.

Overlying these older tertiary clays, especially near the summits of hills, are found beds of unstratified clays and gravels, probably belonging to what has been termed the drift period.

The clays have, no doubt, been formed by the gradual deposition of mud from sluggish rivers, and the very lines of stratification have led to the belief that the whole was a more or less regularly laminated mass. This is, to all appearances true; but it will be shown that there exist in the mass surfaces of least cohesion, which are not parallel to the lines of stratification.

Let us suppose that a slope has been formed, partly by excavating the clay behind, and partly by building up the excavated clay on the top of that which remains *in situ*. If a slip takes place on the slope *a b c*, Fig. 1, it will be found that it originates in the part between *b* and *c*; and the slope will generally assume the shape *a b f*. If now a cutting be made at right-angles to the line of the toe of the slope, after the debris included in the figure *a b f d* has been cut through, a glazed surface extending from *h* to *d* and *f* will be found, behind which the old clay will be apparently as solid as ever.

Above the line of original surface of the ground it will be found that the clay has simply fallen down from the want of support.

Along the cliffs on the coast of the island, in addition to the slips which occur in the manner just described, smaller masses will be found scooped out, as it were, thus—

The portion *a b c*, Fig. 2, slipping round and assuming the position *b d e*. This form of slipping may be observed in slopes which have been entirely excavated in the original clay.

The numerous pools of water, which exist along the face of the clay cliffs, occupy the basins thus formed at *b*.

As before observed, it will be found that the slip has taken place along a glazed surface, of which *a b c* would be the section.

This manner of slipping is only observed in the old clay which has remained *in situ*. It has not been observed in the case of newly formed banks, or even of slopes cut in the recent "drift" clays. With newly formed banks, the slipping will be found to be superficial, the clay having been reduced, near the surface, to a more or less fluid state, by rain or the moisture of the air.

On the other hand, in the case of slips in the old clays, the mass is at the first beginning of the motion, hard and compact, although afterwards, it becomes broken up, and then rendered soft and nearly fluid by moisture. It will also be found that these surfaces, along which the slip takes place, pass from one bed of clay into another, without alteration of direction.

It is considered, as beyond doubt, that the existence of these surfaces of least cohesion, is the cause of most of the slipping in clay slopes, excavated in "the solid."

How these surfaces are formed, seems to be a question of great difficulty. It may be, that the cracks in drying mud, caused by the evaporation of a certain amount of water originally contained in the mass, point to the origin of the surfaces referred to. Pressure, has also been thought to produce a kind of stratification at right angles to its direction, but if we consider that the surfaces are formed in every direction, we can hardly suppose pressure to have been the cause.

It is possible that the mass of the clay may be in a state of partial crystallization, produced by the nature of the material, and assisted by the magnetic force of the earth currents.

The same tendency in rock masses to assume a kind of partial crystallization may be observed in granite quarries, where large surfaces may be seen, forming the masses of granite into roughly hexagonal crystals.

Whatever the cause may be, these surfaces exist.

The manner in which they cause the slip appears to be as follows :—

If *c d*, Fig. 3, be the original surface of the ground; suppose the ground excavated to the right of the line of slope *d h*; and that *b a*, *b c*, are two surfaces of least cohesion, it will easily be seen that the instant that the friction on the surface *b c* is overcome, the whole mass *a b c* will slip out, and consequently the overhanging mass above will break away at another surface, and a slip be produced, similar in appearance to those already described.

Now the surface, *b c* is *at first* very slippery and smooth, so that the slip might occur at once; but if the friction is sufficient at first to retain the mass *a b c* in position, it will be very soon decreased by the penetration of rain along

NOTES ON CLAY.

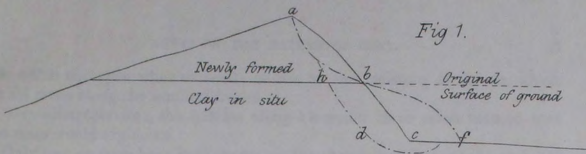


Fig 1.

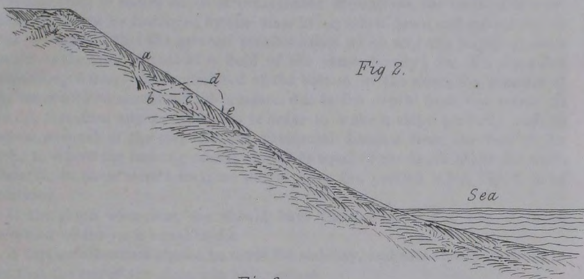
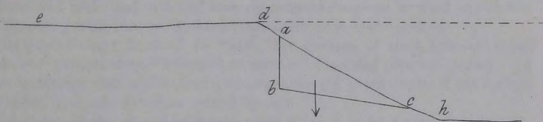


Fig 2.

Fig 3.



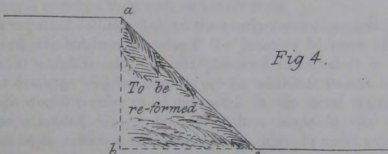


Fig 4.

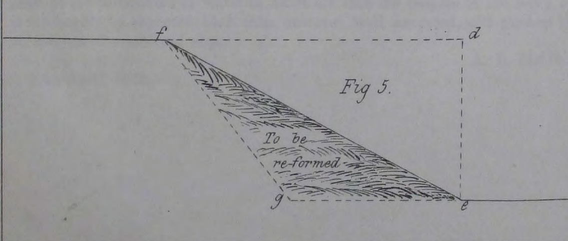


Fig 5.

a b, which will open when exposed; or else by the moisture of the air, which would creep along the smallest fissure.

Very soon, therefore, the friction along *b c* would be so much reduced that the mass would slip down.

Only two surfaces have been shewn on the sketch, but there would probably be several joined together.

With regard to the manner in which the clay should be treated, it is proposed that, to secure slopes of manageable dimensions, the surfaces of least cohesion should be destroyed by the mass being taken down and reformed. It will be observed that the greatest possible effect which any slip might produce would be the same as that of a fluid of the same density; for, if a slip takes place along a nearly horizontal bed at the bottom of the slope, the pressure at the toe would be almost a fluid pressure, due to the depth from the crest. It would, therefore, appear necessary, in order to make a slope perfectly safe, to reform so much of the clay that the horizontal distance from the face of the slope to where the forming ceases, should be equal to the depth below the crest. Thus, if the slope were 1 in 1, we should have the portion *a b c*, Fig. 4, to be reformed.

If the slope were less, we should have the portion *c f g*, Fig. 5, to be reformed where *g e* is equal to *d e*.

A further allowance should be made for stability, and care should be taken to see that the toe of the slope was quite secure.

In practice also, the lines *a b*, and *f g*, would not be straight and unbroken, but "benched" back, and in doing this, care should be given to work in the face of the benching with the newly-formed material as it is brought up.

In the case of clay "in situ," in which the surfaces of least cohesion exist, there is no "natural slope" at which it may be depended upon to stand; but the newly formed clay will be found to stand at very great slopes, if the surface be protected from the detrition caused by rain, &c.

The forming of the clay should take place when it is in a slightly soft state, so as to be capable of being well rammed in about 9-inch layers. It should not be worked when hard, or when very soft, or nearly fluid.

If any water is expected to lodge behind the newly-formed portion, it should, of course, be drained off; but in most cases if the junction between the newly formed clay and that which is left "in situ" be well executed, it is not considered likely that drainage will be necessary. In addition to this, the whole surface of the slope would require to be protected in the usual manner. The chief point to be attended to, in dealing with a slope in the way just described, seems to be to reform a sufficiently large mass to resist any possible pressure from behind.

In the case of very large slopes, it would appear best to adopt means to prevent the percolation of water or moist air into the fissures of the clay; but it can hardly be expected that this, however well executed, will prevent the occurrence of occasional slips.

A. B. McH.

27th April, 1870.

PAPER VIII.

CYLINDRICAL STONE LEWIS.

INVENTED BY SAPPER WM. HUGHES, 27TH COMPANY, R.E.;
DESCRIPTION FURNISHED BY LIEUT. WALLER, R.E.

This lewis, the invention of Sapper William Hughes, 27th Company, R.E., is admirably adapted for use with soft stone, such as Malta sandstone, in which holes can be easily bored with an ordinary drill.

It consists of three pieces, with a shackle and pin.

The centre piece, Fig. 3, is flat with a projecting wedge on either side, and a hole in the head for the pin to pass through. The side pieces are semi-cylindrical, with hollow grooves on the inside, corresponding to the wedges on the centre piece. A long slot "a a" Fig. 4, admits of their working freely up and down on the pin. A certain amount of play has to be allowed between the parts.

Fig. 1 shews the lewis in position for dropping into a stone; the hole for its reception should be about 9 inches deep, and of a slightly larger diameter than the lewis itself. On the strain being brought to bear, the centre piece is drawn up, and the wedges force out the side pieces, pressing them with a powerful grip against the side of the hole.

Fig. 2 shews the extreme position which the lewis is capable of assuming. To remove it, a smart blow on the projecting head of the centre piece is all that is necessary; the pin, carrying with it the shackle and centre piece, slides down the slots in the side pieces; the lewis assumes its original shape (Fig. 1), and is easily removed from the hole.

The following advantages are claimed over the rectangular lewis:—

1st. It is never necessary to take it to pieces.

2nd. Greater safety. It grips a larger surface, and the grip becomes more powerful as the strain increases.

3rd. Saving of time. The hole can be bored by any labourer in a few seconds, while it takes a skilful mason 15 minutes to make the hole for a rectangular lewis.

The cylindrical lewis has been successfully used for some time past, on the works at Malta, and stones of more than two tons weight have been safely lifted with it.

The Committee of the Malta Naval and Military Industrial Exhibition of 1870, unanimously awarded an extra first prize of £5 to Sapper Hughes for his invention.

S.W.

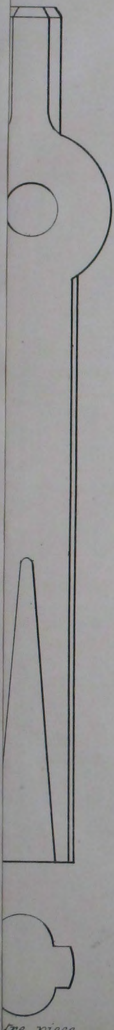
CYLINDRICAL STONE LEWIS.

INVENTED BY ***SAPPER. W. HUGHES***, *27TH CO. R.E.*

MALTA 1869.

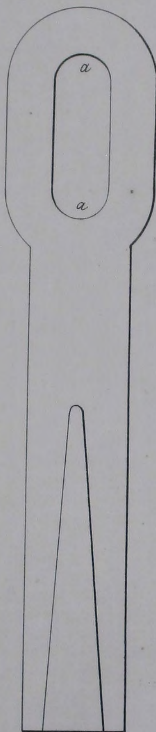
HALF FULL SIZE.

Fig 3.



tre piece.

Fig 4.



Outside piece.

PAPER IX.

ON THE RESISTANCE OF ARMOUR PLATES.

By Lieutenant ENGLISH, R.E.

1.—The discovery, by Major Palliser, of the proper kind of material and shape of head for armour-piercing projectiles has, apparently, rendered impracticable the task of the naval architect, who may have to design a structure capable at once of protecting, and of resisting, the guns of the present day, and has seriously increased the difficulties before the military engineer.

In the latter case, however, the discovery referred to has at any rate enabled us to know the worst that the artillery can do with their present means, and to estimate, nearly, what has to be provided to meet still heavier guns.

Four or five years ago, whilst many points in the subject of ordnance and armour were still in the dark, it was impossible to say, but that some simple and easy change in the details of artillery might not, as actually happened in this case, greatly increase the power of attack.

We may now however fairly reckon upon being able, by the light of experiments at Shoeburyness, to foresee the worst effect upon armour plates of any projectile within the limits of weight and velocity at present reached.

The object of this paper is to supply a means of calculating, nearly, the effects which would be produced by an extension of these limits; and thus to enable us to consider, in anticipation of direct experiment, the necessary increase of thickness and cost required to withstand the guns of the future.

Without the introduction of chilled projectiles, it would have been almost impracticable to do this at all, on account of the difficulty of apportioning the amount of energy expended upon the shot and upon the plate, respectively.

Whilst projectiles were employed made of materials which underwent an appreciable change of shape during impact, it would have been necessary, in order to determine the energy expended upon them, to calculate their distortion at any instant, and this would have been very difficult. In a good chilled projectile, however, there appears to be no sensible change of shape under the severest single blow; and even though it may be broken and fall to pieces, yet, if all the fragments were collected and put together, the shot might be reproduced in exactly its original form.

The same rigidity is observed in the best, though not by any means in all, of the projectiles with chilled heads and bodies cast in sand, which are now being supplied in order to meet the difficulties of manufacturing shot entirely chilled. This result is as much due to the form adopted for the heads of the service projectiles, as to the material employed, for it has been found by experiment, that when a shot passes through two separate plates, with an intervening air space, the fragments, into which it is broken, on striking the first plate, are completely disintegrated by the second blow, and reduced to a kind of paste.

It is therefore assumed, in this paper, that the projectile may be considered as a rigid body; and it has only to be determined in what manner the energy of the blow is absorbed on striking an armour plate, if none is expended on the shot.

It may be here observed that the following calculations are not put forward as an attempt at an exact or general solution of this problem, but simply as an endeavour to account tolerably nearly for the amount of energy which must be absorbed by an armour plate, in order to produce the principal results which are observed, from experiment, to follow the blow of a service Palliser projectile. In consequence, many modes of absorbing energy, such as bending the plate, stopping the rotation of the shot, &c., are neglected, as they do not appear seriously to influence the result.

2.—Two cases only will be considered—first (A), the determination of the amount of energy required to force a shot of given dimensions to penetrate to various depths into a solid mass of armour-plate; and, secondly (B), the determination of the amount of energy required to force a shot of given dimensions to perforate completely various thicknesses of armour-plate.

(A.) The energy absorbed by a solid mass in resisting a shot may be regarded as made up of (1) the energy absorbed in increasing the diameter of an indefinitely small hole supposed to be bored through the mass in the prolongation of the axis of the shot, to a size sufficient to admit that part of the shot which enters the plate, the latter being considered as an indefinitely thick hollow cylinder surrounding the shot; and (2) of the energy absorbed in frictional resistance to the relative motion of the shot and plate during penetration.

It is assumed, for the sake of simplicity, that the material of which the armour-plate is composed is homogeneous, and that, under a force of tension or of compression, the change of length does not commence at all until a certain definite force is applied, in each case, per unit of area; and that the changes of length, after this point, increase uniformly in given ratios with the forces applied. This is a further simplification of the assumption, made in Paper X, Volume XVIII, that the changes of length increased uniformly, in certain ratios to the forces, up to certain limits, and that after those limits they continued to increase uniformly, but in different ratios.

The points at which the alterations of length commence under tensile or compressive forces, and the ratios of alteration of length to force are assumed such, that the amounts of energy absorbed in stretching the material to its breaking point, or in compressing it until it is entirely forced out laterally, agree with the mean of the amounts ascertained from several experiments made upon armour plates, as explained in Paper X, Vol. XVIII, and shewn in diagram 2 of that paper.

The diminution of tension in successively larger rings of fibres surrounding the shot is taken as following the law ordinarily assumed for thick hollow cylinders, which is given in Rankine's "Applied Mechanics," page 290. It is evident, on this supposition, that the rings of plate immediately surrounding the shot will, by the entrance of the head, be first extended, then broken, and then compressed.

The energy absorbed by the plate will be that required to extend to the breaking point, and then to compress to various amounts, the broken rings of plate, and to extend to various amounts the unbroken rings surrounding these.

The energy absorbed in friction is found on the assumption, that the resistance to the relative motion of the shot and plate is equal to the force required to shear through a section of the plate of the same area as the common surface, in contact, of the shot and plate. The resistance cannot, evidently, exceed the amount thus found, and probably approaches it nearly, as this method of calculation is equivalent to allowing a co-efficient of friction between the shot and plate of about ·275, which does not seem too great under such intense pressure.

The portion of plate immediately surrounding the shot appears from experiment to be in almost a fluid state during impact, for it invariably fills up any crevices or holes existing in the head of the shot.

(B.) The energy absorbed in perforating a plate of given thickness is calculated on the assumption that up to a certain penetration, the action is the same as that found to exist between the shot and a solid mass; but that, at this point the pressure in the direction of the shot's motion becomes so intense as to shear out the cylinder of plate in the path of the shot, or rather, to displace a truncated cone from the back of the plate, as is observed to occur in experiment.

Every part of this cone, during its separation, appears to be stretched to the breaking point, thereby absorbing a certain amount of energy.

The remaining energy required to effect complete perforation is considered to be made up of that necessary to enlarge the hole formed through the plate, by the displacement of the cone, to the size of the body of the shot, and of the amount absorbed in frictional resistance during this enlargement.

3.—The details of the necessary calculations, and the formulæ derived from them will be found in appendices A and B.

From these it will appear that, when shot of the same form of head but of different radii, either penetrate into a mass to any depths, or perforate plates of any thicknesses having given proportions to their respective radii, an amount of energy will be absorbed varying as the cube of the radius; and in this limited sense only, the rule laid down in the "Report on the Penetration of Iron Armour Plates by Steel Shot," by Captain Noble, R.A.,—that the energy per inch of circumference, required to perforate a plate, varies with the squares of the thicknesses,—still seems to hold good.

4.—The numerical results worked out from the formulæ thus found, on applying them to the service pattern of shot, with heads struck to a radius equal to once and a half the diameter of the shot, are as follows, if R represents the radius, in feet, of the body of the shot:—

For penetration—

Depth of Penetration.	Foot Tons of Energy.
R	R^3
$0{\cdot}1\dot{6}$	47·17
$0{\cdot}\dot{3}$	401·64
0·5	1220·01
$0{\cdot}\dot{6}$	2603·00
$0{\cdot}8\dot{3}$	4631·00
1·0	7341·70
$1{\cdot}1\dot{6}$	10749·10
$1{\cdot}\dot{3}$	14861·90
1·5	19636·20
$1{\cdot}\dot{6}$	25091·10
$1{\cdot}8\dot{3}$	31267·50
2·0	38049·80
$2{\cdot}1\dot{6}$	45461·80
$2{\cdot}\dot{3}$	53484 30
2·5	62103·50
$2{\cdot}\dot{6}$	71321·30
$2{\cdot}8\dot{3}$	81136·70
3·0	91550·50

and for perforation—

Thickness of Plate.	Foot Tons of Energy.
R	R^3
$1{\cdot}1\dot{6}$	21850·2
$1{\cdot}\dot{3}$	23434·8
1·5	25968·8
$1{\cdot}\dot{6}$	30203·9
$1{\cdot}8\dot{3}$	36309 7
2·0	44083·2
$2{\cdot}1\dot{6}$	53494·3
$2{\cdot}\dot{3}$	64821·3
2·5	77819·8
$2{\cdot}\dot{6}$	92559·2
$2{\cdot}8\dot{3}$	109935·1
3·0	134041·6

For plates of less thickness than about the radius of the shot, so many elements of uncertainty are introduced, owing to the probability of the bending or dishing of the part of the plate surrounding the shot, that it is not considered advisable to attempt any calculation concerning their perforation.

5.—The diagrams A, and B, shew the results of the formulæ applied to the service shot of 7 in., 9 in., 10 in., and 12 in. diameter, and 115, 250, 400 and 600 lbs. weight, respectively, and to the proposed shot for the 35-ton gun, now making, of 11·6 in. diameter and 700 lb. weight.

The results actually observed from experiment are denoted by circles on the diagrams, and are as follows:—

Date.	No. of Round.	Description.	Feet per second Velocity.	Depth of Penetration. inches.	Thickness perforated. inches.
23rd June, 1868	1530	7-in. shell, 1·5 D head	1413	8·45	—
17th " "	1518	10-in. shell, "	1260	12·2	—
16th " "	1507	12-in. shell, "	1159	14·0	—
18th " "	1528	12-in. shell, "	1173	12·3	—
5th " "	?	9-in. shot, 1 D head.	1340	—	10
12th June, 1867	?	7-in. shot, 1·25 D head	1244	—	7
8th Oct., 1868 ..	$\frac{419}{P}$	7-in. shot, "	1331	—	8
Average result of proof of armour		7-in. shot, "	950	—	5·25

No experiments have yet been made with shot having heads of the service pattern, but it is probable that the results, under similar circumstances, would be in excess of those given above, and would not differ much from them, espepecially in perforation.

It should be borne in mind that the formulæ are only strictly applicable, if the weight of the shot is inconsiderable in proportion to the weight of the plate; and for plates of small dimensions the total amount of energy absorbed is to the amount shewn above, as the total weight of plate and shot is to the weight of plate only; the difference between the two amounts of energy being absorbed in giving motion to the plate.

The results of the formulæ, as far as can be inferred from experiment, are also applicable to determine the effect of service shell, as the bursting charge does not make any material difference.

APPENDIX A.

PENETRATION.

1.—Let the weight of the shot in tons be .... w
,, striking velocity in feet per second v
,, radius of body in feet .... R
,, radius of head at any point .... r
,, radius to which curve of head is struck .... $\frac{R}{s}$

Assuming that the material of which the plate is composed undergoes no elongation under a tensile force E per unit of area, and that the elongation increases uniformly with the force, between E and the breaking tensile force P per unit of area; the ratio of the original length of any fibre to its elongation under a force P per unit of area being as $1 : n$, and therefore the ratio of the original to the broken length being as $1 : 1 + n$: also, that the material undergoes no compression under a compressive force F per unit of area, the compression increasing uniformly with the force between F and a force Q, per unit of area, sufficient to force out the material laterally so as to leave an indefinitely small thickness over the area subjected to pressure; then the values corresponding to the mean of experiments made by Mr. Kirkaldy for the War Department, upon armour plate, both crossways and lengthways, are as follows:—

$E = 1672$ tons per square foot.
$P = 2424$,, ,,
$F = 3857$,, ,,
$Q = 12536$,, ,,
$n = 0{\cdot}125$,, ,,

Assuming also that the diminution of tension in successively larger rings of fibres in a cylinder subjected to a bursting pressure follows the law ordinarily stated for thick hollow cylinders; so that if y_P and y_E be the strained radii of rings under tensions P and E respectively, per unit of area, and therefore $\frac{y_P}{1+n}$ and y_E the original radii of these rings, and if y be the original radius of a ring under an intermediate tension p per unit of area;

$$\frac{p}{P} = \frac{\left(\frac{y_P}{1+n}\right)^2 (y_E^2 + y^2)}{y^2 \left\{y_E^2 + \left(\frac{y_P}{1+n}\right)^2\right\}}$$

$$\text{and } p = P \, . \, \frac{y_P^2 (y_E^2 + y^2)}{y^2 \left\{y_E^2 (1+n)^2 + y_P^2\right\}} \qquad (1.)$$

since y_E may be taken as the external radius of the cylinder, for there is no extension of rings of greater radii, and, consequently, not necessarily any force acting upon them.

Hence, if $p = E$

$$y_E^2 = \left(\frac{2P - E}{E}\right)\left(\frac{y_P}{1+n}\right)^2 \qquad (2.)$$

Assume also that the area, measured at right angles to the axis of the shot, of the section of any ring under tensile force remains constant, *i.e.*, that the length of a cylinder is unaltered by a bursting strain.

2.—Considering, first, a lamina of the plate at right angles to the axis of the shot, of thickness dx, at a distance x, measured along the axis, from the point of the shot; this lamina may be taken as made up of a succession of rings of broken fibres, now under compression, whose internal radius is now r, and external radius y_P, and of a succession of rings enclosing these, of fibres under tension; the internal radius of these being y_P, and external radius y_E; the rings of greater radius than y_E not being affected.

The radii y_P and y_E vary with r, and the energy absorbed by the lamina is that required first to stretch to the breaking point, and then to compress the broken rings, and to stretch to various amounts the unbroken ones.

3.—By the ordinary formulæ, if q_P be the radial or bursting pressure per unit of area corresponding to a circumferential tension P of the ring whose radius is y_P

$$q_P = P \cdot \frac{y_E^2 - \left(\frac{y_P}{1+n}\right)^2}{y_E^2 + \left(\frac{yP}{1+n}\right)^2}$$

$$= P - E$$

Hence the total radial pressure between the shot and the lamina

$$= (P - E) \cdot 2\pi y_P \cdot dx \qquad (3.)$$

The original radial breadth of broken rings is $\frac{y_P}{1+n}$, and since it is assumed that the area remains constant under tension; the breadth, when the breaking point is reached, and the length increased in the ratio $1 : 1 + n$, will be

$\frac{y_P}{(1+n)^2}$; and the broken rings may be considered as forming an indefinite number of triangular prisms, of uniform height $\frac{y_P}{(1+n)^2}$, the sum of their bases being $2\pi \,.\, y_P$, and carrying a total pressure $(P - E)\, 2\pi\, y_P \,.\, dx$.

If z be the distance from the apex, before compression, in one of these prisms, of a circumferential layer of thickness dx, the area of this layer will be

$$\frac{z}{\frac{y_P}{(1+n)^2}} \cdot 2\pi\, y_P \,.\, dx = 2\pi\,(1+n)^2\, z\, dx. \qquad (4.)$$

and if z_Q, z_F be the distances from the apex, before compression of the layers in each prism subjected to pressures Q, F, respectively per unit of area.

$$z_Q = \frac{y_P \,.\, (P - E)}{(1+n)^2 \,.\, Q} \qquad (5.)$$

$$z_F = \frac{y_P}{(1+n)^2} \,.\, \frac{P - E}{F} \qquad (6.)$$

The area of the layer under pressure Q

$$= 2\pi\,(1+n)^2\, z_Q\, dx$$

$$= 2\pi\, y_P \,.\, \frac{P - E}{Q} \,.\, dx \qquad (7.)$$

and the work of compression, for any value of z less than z_Q, since the material is wholly displaced laterally

$$= \frac{Q+F}{2} \times 2\pi\,(1+n)^2\, z \,.\, dx \,.\, dz$$

Integrating this expression with regard to z, between the limits

$$z = 0,\ z = \frac{y_P}{(1+n)^2} \,.\, \frac{P - E}{Q}$$

we obtain

$$\left.\begin{array}{r}\text{Work of all the layers}\\ \text{totally compressed ..}\end{array}\right\} = \frac{Q+F}{2}\left(\frac{P-E}{Q}\right)^2 \pi \left(\frac{y_P}{1+n}\right)^2 \qquad (8.)$$

4.—For values of z greater than z_Q, from equations (3) and (4), the pressure per unit of area on a layer distant z from the apex before compression

$$= \frac{P - E}{z} \cdot \frac{y_P}{(1+n)^2}$$

The compression of a layer, thickness dz, $= \dfrac{\text{pressure per unit} - F}{Q - F} \cdot dz$

$$= \frac{P - E}{Q - F} \cdot \frac{y_P}{(1+n)^2} \cdot \frac{dz}{z} - \frac{F}{Q - F} \cdot dz \qquad (9.)$$

Integrating this expression with regard to z, between the limits $z = z_Q$, $z = z_F$,

$$\left.\begin{array}{r}\text{Total compression}\\ \text{of prisms.........}\end{array}\right\} = \frac{P - E}{Q - F} \cdot \frac{y_P}{(1+n)^2} \cdot \log \frac{Q}{F} - \frac{P - E}{Q} \cdot \frac{y_P}{(1+n)^2} \qquad (10.)$$

Adding this to the original height, from equation (4), of the rings which are entirely forced out laterally, we obtain

$$\text{Total compression of lamina} = \frac{P - E}{Q - F} \cdot \frac{y_P}{(1+n)^2} \cdot \log \frac{Q}{F} \qquad (11.)$$

5.—The work of any layer distant z from the apex = area × compression × mean pressure per unit of area, and from equations (3), (4), (9),

Work of ring

$$= 2\pi (1+n)^2 z\, dx \times \left(\frac{P - E}{Q - F} \cdot \frac{y_P}{(1+n)^2} \cdot \frac{dz}{z} - \frac{F\, dz}{Q - F}\right) \times \frac{\left(\frac{P - E}{z} \cdot \frac{y_P}{(1+n)^2} + F\right)}{2}$$

$$= \frac{\pi}{Q - F} \cdot dx \left\{ (P - E)^2 \cdot \frac{y_P^2}{(1+n)^2} \cdot \frac{dz}{z} - F^2 \cdot (1+n)^2 \cdot z\, dz \right\}$$

Integrating with regard to z, between $z = z_Q$ and $z = z_F$

$$\left.\begin{array}{r}\text{Work of}\\ \text{lamina}\end{array}\right\} = \pi \cdot dx \cdot \frac{(P - E)^2}{Q - F} \frac{y_P^2}{(1+n)^2} \log \frac{Q}{F} - \pi \left(\frac{y_P}{1+n}\right)^2 \frac{(P - E)^2 (Q + F)}{2\, Q^2}\, dx \quad (12.)$$

Adding to this the work of the layers entirely forced out, from equation (8.)

$$\left.\begin{array}{r}\text{Total work of compression}\\ \text{of lamina ....}\end{array}\right\} = \pi\, dx \cdot \frac{(P - E)^2}{Q - F} \cdot \left(\frac{y_P}{1+n}\right)^2 \cdot \log \frac{Q}{F} \qquad (13.)$$

and with the values assumed for constants

$$\text{Foot-tons of energy absorbed} = \pi \cdot y_P^2 \cdot dx \times 60{\cdot}6835. \qquad (14.)$$

6.—Next, if y be the original radius of any ring under tension, whose radial breadth is dy, and p be the tensile force acting upon it per unit of area

$$\text{Extension of ring} = \frac{p - \text{E}}{\text{P} - \text{E}} \cdot 2\pi y \cdot n$$

Energy absorbed by ring = extension × mean force × area

$$= \frac{p - \text{E}}{\text{P} - \text{E}} \cdot 2\pi y \cdot n \times \frac{p + \text{E}}{2} \cdot dy\, dx$$

$$= \frac{\pi n\, dx}{\text{P} - \text{E}} \cdot (p^2 - \text{E}^2)\, y\, dy$$

For broken rings, in which y is less than $\dfrac{y_{\text{P}}}{1 + n}$.

$$p = \text{P}$$

$$\text{and work of ring} = \pi n\, dx \,.\, (\text{P} + \text{E})\, y\, dy$$

Integrating this expression with regard to y, between the limits $y = 0$, $y = \dfrac{y_{\text{P}}}{1 + n}$

$$\text{total work of all such rings} = \pi n\, dx \,.\, \frac{\text{P} + \text{E}}{2} \cdot \left(\frac{y_{\text{P}}}{1 + n}\right)^2 \cdot \qquad (15.)$$

For rings whose original radii were greater than $\dfrac{y_{\text{P}}}{1 + n}$, from equation (1)

$$p = \text{P}\, \frac{y^2_{\text{P}}}{y^2}\, \frac{\left(y^2_{\text{E}} + y^2\right)}{\left\{y^2_{\text{E}}\,(1 + n)^2 + y^2_{\text{P}}\right\}}$$

and from this and equation (2)

$$y\,(p^2 - \text{E}^2) = \frac{\text{E}^2\, y^2_{\text{E}}}{2y} + \frac{\text{E}^2\, y^4_{\text{E}}}{4y^3} - \frac{3}{4}\,\text{E}^2 y$$

$$\text{Energy absorbed by ring} = \frac{\pi\, n dx}{\text{P} - \text{E}} \left(\frac{\text{E}^2\, y^2_{\text{E}}}{2y} + \frac{\text{E}^2\, y^4_{\text{E}}}{4y^3} - \frac{3}{4}\,\text{E}^2 y\right) dy.$$

Integrating this expression with regard to y between the limits

$$y = \sqrt{\frac{\text{E}}{2\,\text{P} - \text{E}}}\; y_{\text{E}} \quad \text{and} \quad y = y_{\text{E}}$$

Energy absorbed by all such rings

$$= \pi\, ndx \left(\frac{y_P}{1+n}\right)^2 \left\{\frac{2P-E}{P-E} \cdot \frac{E}{2} \cdot \log \sqrt{\frac{2P-E}{E}} + \frac{P-2E}{2}\right\} \qquad (16)$$

and adding the energy absorbed by broken rings from equation (15)
work of tension

$$= \pi\, ndx \left(\frac{y_P}{1+n}\right)^2 \left\{\frac{2P-E}{P-E} \cdot \frac{E}{2} \log \sqrt{\frac{2P-E}{E}} + \frac{2P-E}{2}\right\} \qquad (17)$$

and with the values assumed for constants

Foot tons of energy absorbed $= \pi\, y_P^2\, dx \times 268{\cdot}71$ (18)

and adding equation (14)

$$\left.\begin{array}{l}\text{Total number of foot-tons of}\\ \text{energy absorbed by displacement}\end{array}\right\} = \pi\, y_P^2\, dx \times 329{\cdot}69 \qquad (19)$$

7.—The compression produced in the lamina by enlarging an indefinitely small hole to a radius r is evidently

$$= \frac{y_P}{(1+n)^2} - (y_P - r)$$

Equating this with the compression found by equation (11), we obtain

$$y_P = \frac{(1+n)^2}{\frac{P-E}{Q-F} \log \frac{Q}{F} - 1 + (1+n)^2} \cdot r$$

$$= 3{\cdot}4415 \times r, \text{ with the values assumed.}$$

$$\text{and } y_P^2 = 11{\cdot}8438 \times r^2$$

Hence,

$$\left.\begin{array}{l}\text{foot tons of energy absorbed}\\ \text{by lamina, in displacement}\end{array}\right\} = 3904{\cdot}8\, \pi\, r^2 dx \qquad (20)$$

and total work of displacement, in foot tons $= 3904{\cdot}8 \times$ volume displaced (21)

8.—The volume of an ogival head may be found by the following formula: If α be the angle between the axis of the shot and a tangent to the generating curve at the point of the shot, and if θ be the corresponding angle at any other point.

Volume between these limits,

$$= \pi \frac{R^3}{s^3} \left\{ \frac{\sin \alpha\,(2 + \cos^2 \alpha) - \sin \theta\,(2 + \cos^2 \theta)}{3} - (\alpha - \theta) \cos \alpha + (\cos \theta - \cos \alpha) \sin \theta \cos \alpha \right\} \qquad (22)$$

9.—Let r_θ be the radius of the head of the shot, at the point to which θ refers; then, in order to determine the energy absorbed in friction, considering first a band or ring of the surface of the shot, of breadth, $\frac{R}{s}\,d\theta$, we may assume, as before shewn, that the radial pressure per unit of area between the shot and the plate is Q.

Assuming also that the plate immediately surrounding the shot is in the condition of a fluid, and that the frictional resistance varies with the pressure; we see that the frictional resistance per unit of area is constant and independent of the radius, and further, that it cannot exceed the force required to shear the metal of the plate. This force will be, theoretically, the same as the tensile force per unit of area required to separate a section of the metal inclined at 45° to the direction of the shearing strain, and therefore equal to $\sqrt{2}$ P, per unit of area exposed to shearing, provided that the metal is confined, as in the present case, so as to offer its full resistance over the whole section at the same instant. This value must not be confused with what is usually termed resistance to shearing, in the case of rivets, &c., which are cut by a sharp edge.

If θ_0 be the value of θ corresponding to the point where the shot enters the plate, we may assume the frictional work of a ring of the shot's surface = shearing force × area of ring × distance passed through in the plate

$$= \sqrt{2}\,P \times 2\,\pi\,r\,\frac{R}{s}\,d\,\theta \times \frac{R}{s}\,(\theta - \theta_0)$$

For an ogival head

$$r = \frac{R}{s}.\ (\text{Cos}\ \theta - \text{Cos}\ \alpha)$$

and substituting this value

$$\text{work of ring} = 2\,\pi\,.\,\sqrt{2}\,P\,\frac{R^3}{s^3}\Big(\text{Cos}\ \theta - \text{Cos}\ \alpha\Big)\Big(\theta - \theta_0\Big)d\theta$$

Integrating this expression between the limits $\theta = \theta_0$, $\theta = \alpha$, we obtain frictional work

$$= 2\,\sqrt{2}\,\pi\,.\,P\,\frac{R^3}{s^3}\left\{(\alpha - \theta_0)\ \text{Sin}\ \alpha + \text{Cos}\ \alpha - \text{Cos}\ \theta_0 - \frac{\text{Cos}\ \alpha}{2}\,(\alpha - \theta_0)^2\right\} \quad (23)$$

If the entire head of the shot enters the plate $\theta_0 = 0$, and

$$\text{Frictional work} = 2\sqrt{2}\,\pi\ .\ P\,\frac{R^3}{s^3}\left(\alpha\ \text{Sin}\ \alpha + \text{Cos}\ \alpha - \alpha^2\,\frac{\text{Cos}\ \alpha}{2} - 1\right) \quad (24)$$

and for service shot, with head struck to a radius of one and a half times the diameter, this becomes

$$\text{Frictional work of entire head} = 33590\ R^3\ \text{foot tons.}$$

10.—If $\frac{mR}{s}$ be the length of that part of the body of a shot which has penetrated a plate at any moment, by similar reasoning to the above we obtain

$$\left.\begin{array}{l}\text{Frictional work of}\\ \text{bands of head}\ldots\end{array}\right\} = 2\,\sqrt{2}\,P\,.\,\pi\,r\,\frac{R}{s}\,d\theta \times \left(\frac{R}{s}\,\theta + \frac{m}{s}\,R\right)$$

Substituting for r its value, and integrating between the limits $\theta = 0$, $\theta = \alpha$

Frictional work of head

$$= 2\sqrt{2}\,P.\,\pi\,\frac{R^3}{s^3}\left(\alpha \sin\alpha + \cos\alpha - \frac{\alpha^2}{2}\cos\alpha - 1 + m\sin\alpha - m.\,\alpha\cos\alpha\right)$$

and for service shot

$$\text{Work in foot tons} = 33590\ R^3 + 6856\ \pi\,\frac{R^3}{s^3}\ m\,(\sin\alpha - \alpha\cos\alpha)$$

The work of a band of the body, distant x from the head, of breadth dx, $= \sqrt{2}\,P \times 2\,\pi\,R dx \times \left(\frac{m}{s}\,R - x\right)$ by similar reasoning; and integrating this expression between the limits $x = 0$, $x = \frac{m}{s}\,R$.

Frictional work of body $= \sqrt{2}\,\pi P\ R^3.\,\frac{m^2}{s^2}$; hence the total frictional work in foot tons, of the shot, for penetrations beyond the head

$$= \frac{2\sqrt{2}\,P}{s^3}\,\pi\,R^3\left\{\frac{m^2 s}{2} + \alpha\sin\alpha + \cos\alpha - \frac{\alpha^2}{2}\cos\alpha - 1 + m\,(\sin\alpha - \alpha\cos\alpha)\right\} \quad (25)$$

11.—By adding the number of foot-tons of energy absorbed by friction, from equation (23) or (25), as the case may be, to the number of foot-tons absorbed in displacing the metal, from equation (21), the total number of foot-tons of energy required to effect any given penetration may be found, and by equating this expression with $\frac{w\,v^2}{2\,g}$, the striking velocity of the projectile can be determined, if the weight be known, or *vice versa.*

APPENDIX B.

Perforation.

1.—Assuming the same notation as in Appendix A, it has been shewn that when a projectile has entered an armour plate, the pressure per unit of area between it and the plate may be estimated at Q, hence the force tending to shear out the portion of plate in front of that part of the head of the shot at which the radius is r, will be $\pi\,r^2\,Q$.

Assuming, as appears probable from experiment, that the portion of plate thus driven out is separated by direct tensile stress; the broken surface making a constant angle of 45° with the surfaces subjected to shearing, or in other words, that a truncated cone of plate, with a vertical semi-angle of 45°, and least radius r, is detached: then, as this cone is not confined laterally, the force tending to separate it from the rest of the plate must obviously be most intense, immediately round the shot; and when separation takes place, must be equal to P per unit of area, at this part.

Assuming that this force diminishes uniformly, from the value thus given, to nothing at the junction of the conical surface with the hinder surface of the plate: let t be the height of the truncated cone, measured along the axis of the shot, then considering a thickness dx, measured at right angles to this direction, and at a distance x from the top of the cone,

$$\text{the broken surface of lamina} = 2\pi(r+x) \times \sqrt{2}.\, dx$$

$$\text{and tensile force per unit of area on this surface} = \text{P}.\, \frac{t-x}{t}$$

$$\text{hence tension upon surface of lamina} = 2\sqrt{2}.\, \pi\, \frac{\text{P}}{t}\, (t-x)\,(r+x)\, dx.$$

Integrating this expression with regard to x between the limits $x=0$, $x=t$.

Resistance to separation $= \sqrt{2}\,\pi\,\text{P}.\left(\frac{t^2}{3} + tr\right)$, equating this with $\pi r^2\, \text{Q}$

$$\text{we obtain } t = r \times \left(\sqrt{\frac{3\,\text{Q}}{\sqrt{2}\,\text{P}} + \frac{9}{4}} - \frac{3}{2}\right)$$

or with the values of P and Q assumed, $t = 2{\cdot}136\, r$ (1)

2.—To determine the indentation produced in the plate before the truncated cone is separated; let x_β be the indentation required, β the angle made with the axis by the curve to which the head is struck, at the top of the truncated cone, and let r_β be the radius of the head at this point; then if T be the total thickness of the plate,

$$t = \text{T} - x_\beta + \frac{\text{R}}{s}\,(\sin\alpha - \sin\beta)$$

$$x_\beta = \text{T} + \frac{\text{R}}{s}\,(\sin\alpha - \sin\beta) - 2{\cdot}136\, r_\beta$$

and since $r_\beta = \frac{\text{R}}{s}\,(\cos\beta - \cos\alpha)$ the minimum value of x_β will occur when $\cot\beta = 2{\cdot}136$, or $\beta = 25^\circ\, 5'$ or, in words, the projectile will penetrate into the plate as into a solid mass, until the radius at the point where the curve to which the head is struck makes an angle of $25^\circ\, 5'$ with the axis, and is $\frac{1}{2{\cdot}136}$ of the thickness of plate in front of this part of the shot.

From the indentation thus found, the energy absorbed in penetrating the plate, considered as a solid mass, can be determined according to the formulæ of Appendix A.

3.—If the thickness of the plate T be so small, compared with the radius of the shot, that r_β is greater than $\frac{T}{2 \cdot 136}$, the required energy must be calculated as being that which will produce such an indentation that the radius of the shot r_β, at the point at which it enters the plate, is equal to $\frac{T}{2 \cdot 136}$, the value of β increasing in proportion to the thickness of the plate.

4.—The volume of the truncated cone displaced is $\frac{\pi}{3}\left\{\left(r_\beta + t\right)^3 - r_\beta{}^3\right\}$, and all parts of it appear from experiment to be strained to the breaking point; hence from Appendix A, it will be readily seen that the energy absorbed in this manner will be

$$= \frac{P + E}{2} \times n \times \frac{\pi}{3}\left\{\left(r_\beta + t\right)^3 - r_\beta{}^3\right\} \dots\dots\dots \quad (2)$$

5.—The volume of metal further displaced by the shot, in making a clean hole radius R, through the plate, is the difference between the volume of a cylinder of radius R, and length equal to the distance from the front of the plate to the surface of the cone, and the volume of that part of the shot and displaced cone lying within this cylinder, or difference required

$$= \pi R^2 - \frac{R}{s} \sin \beta - \int_{x_\beta}^{o} \pi r^2 \, dx + \pi R^2 \left(R - r_\beta\right) - \frac{\pi}{3}\left(R^3 - r^3_\beta\right)$$

for plates of such thickness that the entire head of the shot has entered, before the separation of the cone; and the energy in foot-tons absorbed in effecting this displacement, according to the formulæ of Appendix A

$$= 3904 \cdot 8 \times \text{volume displaced} \dots\dots\dots\dots\dots\dots \quad (3)$$

6.—For plates of such thickness that the head of the shot has not entirely entered, before the cone is separated; let γ be the angle made with the axis by the curve to which the head is struck, at the surface of the plate, then for the expression of section 5, for volume further displaced, must be substituted

$$\pi \frac{R^3}{s^3} (\sin \beta - \sin \gamma) - \int_{x_\beta}^{x_\gamma} \pi r^2 \, dx + \pi R^2 (R - r_\beta) - \frac{\pi}{3}(R^3 - r^3{}_\beta) \dots \quad (4)$$

and as in equation (3)

Foot tons of energy absorbed $= 3904 \cdot 8 \times$ volume thus found.

7.—The energy absorbed by friction during this further displacement may be estimated by considering first a band or ring of the surface of plate in contact with the shot, of breath $\frac{R}{s} d\theta$.

Energy absorbed by ring $= \sqrt{2}\, P \times 2 \pi r \frac{R}{s} d\theta \times \frac{R}{s}\, \theta.$

Integrating this expression between the limits $\theta = 0$, $\theta = \beta$.

Energy absorbed in friction

$$= 2\pi\sqrt{P}\frac{R^3}{s^3}\left(\beta\sin\beta + \cos\beta - \frac{\beta^2}{2}\cos\alpha - 1\right) \ldots\ldots\ldots\ (5)$$

This expression may be taken as approximately correct for all thicknesses of plates within practical limits, on the assumption that for small thicknesses the plate immediately surrounding the shot moves with it, as long as the diameter of the shot in contact continues increasing, *i.e.*, until the head has entirely entered the plate.

8.—To determine the energy absorbed in frictional resistance to the body of the shot in following the head through the hole thus formed in the plate; first, for plates of such thickness that the entire head has not entered before the cone of plate is separated. Considering a ring of the body of breadth dx, the resistance offered to this $= \sqrt{2}\ P \times 2\pi\ R\ dx$, and the space through which this resistance is exerted may be assumed as equal to the thickness of the unmoved part of the plate, which is in contact with the shot, or $= T - t$, hence

$$\text{Energy exerted against band} = \sqrt{2}\ P\ 2\pi\ R\ (T - t)\ dx.$$

Integrating this expression between the limits 0 and $T - t$, that is, assuming that after the head of the shot is free, each band of the body of the shot which is in contact with the plate scrapes off and carries with it a ring of plate, thereby leaving room for the remainder of the body to pass, we obtain

$$\left.\begin{array}{l}\text{Total frictional energy}\\ \text{absorbed in resisting}\\ \text{body of shot}\ldots\ldots\end{array}\right\} = 2\sqrt{2}\,\pi\, P\, R\,(T - t)^2 \text{ foot tons}\ldots\ldots\ldots\ldots\ (6.)$$

9.—Next, for plates of greater thickness, in which a portion of the body of the shot has entered before the cone is separated; if $\frac{m}{s}$ R be the distance entered, we must add to the amount of energy found by the formulæ of the last section, an amount for each ring of breadth dx equal to

$$2\sqrt{2}\,\pi\, P\, R\, dx\,(x + T - t).$$

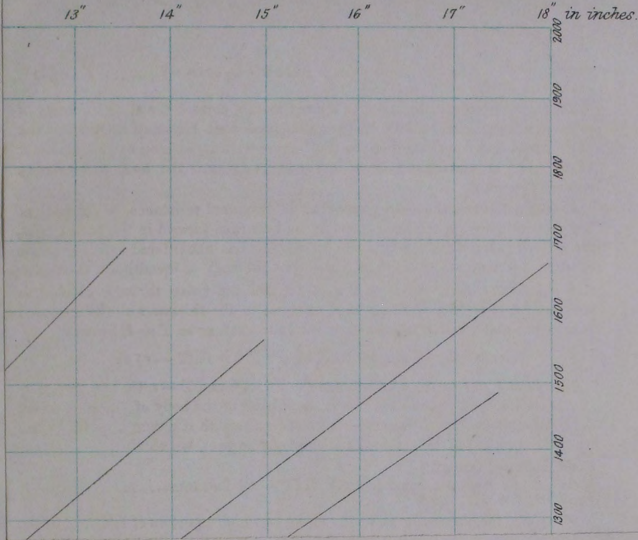
Integrating this expression with regard to x between the limits $x = o$, $x = \frac{m}{s}$ R

$$\left.\begin{array}{l}\text{Total additional}\\ \text{energy required}\end{array}\right\} = 2\sqrt{2}\,\pi\, P\, \frac{m}{s} R^2 \left\{\frac{m}{s}\ \frac{R}{2} + (T - t)\right\} \qquad (7)$$

10.—By adding together the amounts of energy absorbed in the various ways indicated in the preceding sections, and equating the result with $\frac{w v^2}{2g}$, the energy stored up in the shot, a formula is obtained by which the velocity may be determined if the weight is known, or *vice versâ*.

T. E.

to solid Armour
velocities.



PAPER X.

ON THE TRANSVERSE STRENGTH OF RAILWAY IRON WHEN USED FOR PURPOSES OF CONSTRUCTION.

BY COLONEL G. GRAHAM, V.C., R.E., C.B.

1.—In future campaigns, railway iron must come into extensive use for field engineering purposes, such as repairing bridges, strengthening earthen parapets, constructing temporary bomb-proofs and magazines, &c., &c. This was the case, I am informed, at the siege of Charleston, and later in the works of the defences about Dresden, thrown up by the Prussians in 1866, as described in Vol. XVI. of the Professional Papers.

2.—In his observations on these works (page 55), Captain Webber calls notice to "the bomb-proof covering of the caponiers, magazines, and barracks, "into the wooden construction of which is introduced the use of old railway "irons as a support to concrete under the earth, producing a water-tight roof "of considerable strength and great cheapness, which, I am told, the Prussians "had subjected to ample tests as a resistant to the effects of vertical fire."

3.—By the section shown on Pl. X of Captain Webber's paper, the rails thus used appear to have been of the ordinary double-headed type, and to have been laid close together with a span of from 12 to 13 feet, covered with about 6 feet of concrete and earth (18 inches of the former to about 4 ft. 6 in. of the latter). The bearing power of the roof thus constructed would be about 14 cwt. per square foot, while the actual weight of the material supported would be about 7 cwt., including the weight of the rails, thus leaving a wide margin for power to resist sudden strains. Another most instructive instance of the application of rails for purposes of construction is shewn in the field work redoubt which was thrown up on the Chatham Lines in 18 hours of continuous work, in August, 1869, when rails were used to cover over the splinter proofs and caponiers.

When reliable detailed accounts can be obtained of the present war, we shall doubtless learn that railway iron, in place of timber beams, has been made great use of on both sides. The only instance that has as yet come to my notice is in an account of the Prussian entrenchments before Metz, dated the 29nd of October, which states that "the Prussians have been constructing numerous casemates covered with batteries. These casemates are roofed with railway rails placed close together and covered with earth."—(*Standard*, Octo-26th, 1870.)

4.—The subject of this paper is the consideration of the transverse bearing strength and deflection of rails thus used, and to suggest the adoption of some simple formulæ for facilitating calculations that have to be made in the field.

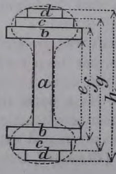
5.—Rails are of great variety of weight and shape ; the sections appended to this paper shew those most commonly used.

The doubled-headed rail (figs. 1, 2, 3, 5), is almost universally adopted for the main lines throughout England, with a few exceptions, such as the Great Western Railway, where bridge shaped rails are used, having wide flanges bearing on longitudinal sleepers; experimental bridge rails have also been introduced on cast and rolled iron bearings. Mr. Unwin, C.E., (who kindly supplied me with some sections of rails) is of opinion that the broad flanged steel rail such as laid down on the Metropolitan Extension Railway, will be the rail of the future (see fig. 13)*. The ordinary lengths of rails vary from 15 to 24 feet.

The following list (taken from Vol. XX. of minutes of proceedings, C.E. Institution, page 280) show the various descriptions of railway bars exported from England, and their destination :—

Europe—France	Formerly the double-headed rail; now the broad bottomed flange rails; also Brunel's and Barlow's systems.
„ Russia, Sweden, Denmark, Austria, and generally throughout Germany	the deep flange rail.
„ Sardinia and Naples	the single-headed rail with chair.
Italy in other parts	the deep flange rail.
Asia—India	the double-headed rail with chair.
" Ceylon	the broad-bottomed flange rail.
Australia	the double-headed rail with chair.
Africa, Egypt	ditto on Greaves' bearings.
America, United States	the broad-bottomed flange rail.
Canada, Great Western	ditto ditto
„ Grand Trunk	the bridge rail on cross sleeper.
Brazil	the double-headed rail.
Chili and Peru	the broad-bottomed flange rail.

7.—Appended to this paper are representative sections of different rails, with the calculations for their respective moments of inertia, the method of making which, it may be as well briefly to summarize.



If I be the moment of inertia of any rectangle $b\,d$, then

$$I = \tfrac{1}{3}\,b\left(\frac{d}{2}\right)^3 + \tfrac{1}{3}\,b\left(\frac{d}{2}\right)^3 = \tfrac{1}{12}\,b\,d^3.$$

See Rankin's useful Rules and Tables, p. 159.

Therefore, by dividing the section of any solid into any number of rectangles (as per margin) we get

$$I = \tfrac{1}{12}\left\{ae^3 + b\,(f^3 - e^3) + e\,(g^3 - f^3) + d\,(h^3 - g^3)\right\}$$

* This opinion seems hardly to be borne out by the most recent practice. In an important line now under construction between Manchester and Liverpool, in which the Engineers of three large railways are concerned, a single-headed steel rail (like fig. 17) has, after mature consideration, been adopted.—ED.

8.—The moment of resistance $= \frac{f_0 I}{y_0}$; when $f_0 =$ the working resistance of the material employed (5 tons in wrought iron per square inch in compression*), I the moment of inertia, and y_0 the distance from the neutral axis to the extreme fibre on the weakest side of the section, (the compression side in wrought iron).

9.—Then by equating the moment of resistance with the moment of pressure, we get, in the case of a beam supported at both ends and loaded in the centre,

when $W =$ total working load in tons,
and $c = \frac{1}{2}$ length of bearing in inches.

$$\frac{W c}{2} = \frac{f_0 I}{y_0}$$

$$\text{and } W = \frac{2 f_0 I}{c y_0}$$

Where the beam is uniformly loaded, the moment of flexure $= \frac{wc^2}{2}$ if $w =$ weight in tons per inch run; and, therefore, $w = \frac{2 f_0 I}{c^2 y_0}$

Since $W = 2 c w = \frac{4 f_0 I}{c y_0}$, the latter equation may be omitted in practice, the load for the centre being doubled when uniformly distributed.

10.—In the case of the bridge and flange rails, the calculation for the moment of inertia is complicated by having previously to determine the centre of gravity for the position of the neutral axis, and by then having to calculate separately the rectangles of the upper and lower flanges. To ensure accuracy in the result, a very careful preliminary measurement and drawing of the rail section would have to be made, and all this would probably require more time than would be available in the field. Even with the most careful calculation, the results obtained can only be regarded as approximate, so much depending upon the quality of the iron and the condition of the rails, the effect of which on the coefficient f_0 could only be determined by experiment. I would, therefore, propose some more rough and ready means of determining the transverse strength of rails, by basing the calculation on some easily obtained data.

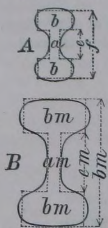
11.—Attached to this paper is a table giving calculations of the moments of inertia for rails of different classes, and to determine the strength of any *similar* rails it is only necessary to find the ratio of any transverse dimension to the corresponding dimension of one of those already calculated, assuming the other dimensions to correspond in the same ratio: then with equal lengths of rails the moments of resistance would be as the cubes of these dimensions. But in rails where these dimensions are very small, and where the sections are always curvilinear, it would be very hazardous to base any calculation on their

* This statement of the strength of wrought iron errs, perhaps on the side of safety, for the purpose under consideration.

accuracy; and I therefore propose taking the *weight* as the standard of comparison, the weight of a yard of rail being a well-recognized datum for identification, and one easily ascertained.

12.—The following simple analysis shews the relations which the weights of equal lengths of similar rails bear to their strength.

Let A, B, be any two similar rails; then



call m the common ratio of sectional dimensions.

G the weight of one yard of A.

G_1 do. do. of B.

then, area of section $A = a\,e + b\,(f - e)$.

do. of do. $B = a\,m\,.\,e\,m + b\,m\,(f\,m - e\,m)$
$= m^2\,\{a\,e + b\,(f - e)\}$

$$\text{Therefore, } \frac{\text{Area of B}}{\text{Area of A}} = m^2$$

$$\text{or } \frac{G_1}{G} = m^2 \quad (1.) \quad \left\{ \begin{array}{l} \text{As the area in square inches multiplied} \\ \quad \text{by } \cdot 28 \times 36 = \text{weight of a yard run.} \end{array} \right.$$

Call I the moment of inertia of A

I_1 do. do. of B

$$\text{then } I = \tfrac{1}{12}\,\{a\,e^3 + b\,(f^3 - e^3)\}$$

$$\text{and } I_1 = \tfrac{1}{12}\,\{a\,m\,e^3\,m^3 + b\,m\,(f^3\,m^3 - e^3\,m^3)\} = \tfrac{1}{12}\,m^4\,\{a\,e^3 + b\,(f^3 - e^3)\}$$

$$\text{Therefore, } \frac{I_1}{I} = m^4 \quad (2.) \text{ and}$$

$$= \frac{G_1^2}{G^2}$$

Call W = safe load, on a length $= 2c$, on rail A } loaded in centre and sup-
W_1 = do. on a length $= lc$, on rail B } ported at both ends.

$$\text{then as before } \frac{Wc}{2} = \frac{f_0\,I}{y_0}$$

$$\text{and } \frac{W_1\,c}{2} = \frac{f_0\,I\,m^4}{y_0\,m}$$

$$\text{therefore } \frac{W_1}{W} = m^3 \qquad (3.)$$

By eliminating m in equations 1 and 3

$$\frac{W_1}{W} = \left(\frac{G_1}{G}\right)^{\frac{3}{2}} \qquad (4.)$$

13.—By means of this equation having a given section of a rail, with its moment of inertia and area, we can at once determine W for any other rail of similar section, the weight per yard being known.

14.—Example: Taking section No. 1 as a base, having weight per yard run $G = 73{\cdot}543$ lbs., to find the safe bearing load on the centre of a rail of the section of No. 5, the weight of which is $G_1 = 76{\cdot}46$ lbs. per yard; length of rail $l = 10$ ft., supported at both ends.

In section No. 1, by equating the moment of resistance with the moment of pressure, we get

$$\frac{Wc}{2} = \frac{f_o I}{y_o} \qquad \left\{ \begin{array}{l} I = 21{\cdot}133 \text{ by previous calculation} \\ c\left(= \frac{l}{2}\right) = 5 \times 12 = 60 \text{ inches} \\ f_o = 5 \text{ tons} \\ y_o = 2{\cdot}55 \text{ inches} \end{array} \right.$$

$$\text{Therefore } W = \frac{2 f_o I}{c\, y_o} = \frac{2 \times 5 \times 21{\cdot}133}{60 \times 2{\cdot}55} = 1{\cdot}35 \text{ tons.}$$

In section No. 5,

call W_1 = working load

G_1 = weight per yard run

I_1 (= moment of inertia) = 22·208

y_{o_1} = 2·55 inches

by equation 4,

$$W_1 = W\left(\frac{G_1}{G}\right)^{\frac{3}{2}} = 1{\cdot}35 \times \left(\frac{76{\cdot}460}{73{\cdot}543}\right)^{\frac{3}{2}} = 1{\cdot}431 \text{ tons.}$$

If calculated by moment of inertia:

$$W_1 = \frac{2 f_o I_1}{c\, y_{o_1}} = \frac{2 \times 5 \times 22{\cdot}208}{60 \times 2{\cdot}55} = 1{\cdot}451 \text{ tons.}$$

Difference in calculations ·02 tons.

15.—Table 1 shows the working loads (W_1 in col. 6) for different sections of rails with lengths of 10 feet, supported at both ends and loaded in centre, calculated from the moments of inertia (as shewn in par. 9).

To find the working loads for any similar rails:

By equation 4 (par. 12) $\dfrac{W}{W_1} = \dfrac{G^{\frac{3}{2}}}{G_1^{\frac{3}{2}}}$

or correcting for length and transposing .... $W = \dfrac{W_1 l_1}{G_1^{\frac{3}{2}}} \times \dfrac{G^{\frac{3}{2}}}{l}$

Call $\dfrac{W_1 l_1}{G_1^{\frac{3}{2}}} = C$

then $W = C \times \dfrac{G^{\frac{3}{2}}}{l}$

C has been calculated for the given sections and is shewn in col. 7, table 1.

W_1 = calculated working load, see Col. 6, Table 1.

l_1 = length in feet = 10.

$G_1^{\frac{3}{2}}$ = weight per yard run in lbs. of known rail.

G = weight of rail similar to known rail.

l = length of ditto.

W = working load of ditto required to be found in tons.

16.—In the cases of the bridge and flange rails, the shapes are so various, that a much greater number of examples than I have been able to collect would be necessary to make this table complete.

Two of these examples, Nos. 5 and 13, are steel rails, and it appears to be the opinion among Civil Engineers, that they will gradually supersede the iron rails. The transverse strength of steel is not easily determined, as it appears to have been very little investigated. (Professor Rankine, on Civil Engineering, page 510). In Vol. XXV. of Proceedings of Civil Engineers, in a paper read on March the 20th 1866, there is a record of experiments made at Mr. Kirkaldy's works on the transverse strength of steel and iron railway bars. Taking the cases of seven steel bars of similar sections (the double-headed type) that were broken with gradually increasing strains, I have shown in Table 2, that the mean coefficient of strength (C) obtained, as shown in column of remarks on Table 2, is ·0418. This would give the strength of the steel rails very nearly double that of the iron rails, the mean coefficient of the double-headed iron rails being ·0213.

DEFLECTION.

17.—Let V, V_1 represent the deflection of two similar rails, then by the formula for deflection : (tabulated from useful Rules and Tables, p. 222.)

$$V = \frac{W n''' l^3 \times 12^3}{8\,E\,I}$$

$$V_1 = \frac{W_1 n''' l_1{}^3 \times 12^3}{8\,E\,I_1}$$

then $\dfrac{V}{V^1} = \dfrac{W}{W_1} \times \dfrac{l^3}{l^3{}_1} \times \dfrac{I_1}{I}$

Substituting values from equations 1, 2, 3, and 4,

$$\frac{V}{V^1} = \frac{G^{\frac{3}{2}}}{G_1{}^{\frac{3}{2}}} \times \frac{l^3}{l_1{}^3} \times \frac{G_1{}^2}{G^2}$$

$$= \frac{\sqrt{G_1}}{\sqrt{G}} \times \frac{l^3}{l_1{}^3}$$

W, W_1 = respective working loads.

l, l_1 = the respective bearings in feet.

$n''' = \frac{1}{6}$ for beams supported at ends and loaded in middle.

or $= \frac{5}{48}$ for beams supported at ends and uniformly loaded.

E = modulus of elasticity = 29,000,000 for wrought iron

I, I_1 = respective moments of inertia.

or calling $\dfrac{V_1 \sqrt{G_1}}{l_1{}^3} = D$

$$V = D \frac{l^3}{\sqrt{G}} \qquad (5).$$

18.—This equation gives the deflection for a rail loaded in the middle. If the same load be distributed uniformly, V will of course vary in the ratio of the values of n''' or as $\frac{1}{6}$ to $\frac{5}{48}$ or 1 : ·625.

If loaded uniformly with the working load (2W) as 1 : 1·25.

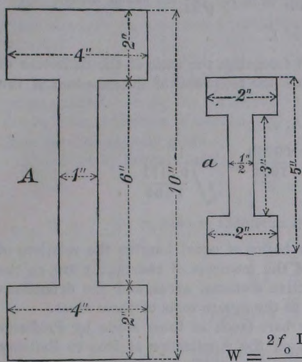
19.—Table 1, cols. 8 to 11, shows the deflections for lengths of 10 feet with working loads, both when in the centre and when uniformly distributed.

Cols. 9 and 11 in this table gives the value of the coefficients D and 1·25 D for rails of sections similar to those referred to, the calculated deflections of which are given in cols. 8 and 10.

In this table all lengths are taken in feet instead of inches, for convenience of calculation.

20.—In the case of *mathematically* similar beams, the results obtained from equations 1, 2, 3, 4, 5, will be found identical with those got by the ordinary method of calculation.

Thus suppose A, a to be two similar rolled iron beams where m (the ratio of the sectional dimensions) $= 2$



To find the working loads W, W_1 and deflections V, V_1,

the length of each beam $l = 10$ feet

$I, I_1 =$ respective moments of inertia

$$f_o = 5 \text{ tons}\ ; \ c = \frac{l \times 12}{2}\ ;$$

$$y_o = 5,\ y_{o_1} = 2{\cdot}5$$

$$n''' = \tfrac{1}{6},\ E = 29{,}000{,}000$$

In beam A

$$I = \tfrac{1}{12}\{1 \times 6^3 + 4 \times (10^3 - 6^3)\}$$
$$= 279{\cdot}33$$

sectional area $= 6 + 4 \times (10 - 6)$
$= 22$ square inches

$$W = \frac{2 f_o I}{c\, y_o} = \frac{2 \times 5 \times 279{\cdot}33}{5 \times 12 \times 5} = 9{\cdot}311 \text{ tons}$$

$$V = \frac{n''' W c^3}{E I} = \frac{9{\cdot}311 \times (5 \times 12)^3 \times 2240}{6 \times 29{,}000{,}000 \times 279{\cdot}33}$$

$$= {\cdot}09269 \text{ inches.}$$

In beam a

$$I_1 = \tfrac{1}{12}\{{\cdot}5 \times 3^3 + 2 \times (5^3 - 3^3)\} = 17{\cdot}458.$$

Sectional area $= {\cdot}5 \times 3 + 2 \times (5 - 3) = 5{\cdot}5$ square inches.

$$W_1 = \frac{2 f_o I_1}{c\, y_{o_1}} = \frac{2 \times 5 \times 17{\cdot}458}{5 \times 12 \times 2{\cdot}5} = 1{\cdot}164 \text{ tons.}$$

$$V_1 = \frac{n''' W_1 c^3}{E I_1} = \frac{1{\cdot}164 \times (5 \times 12)^3 \times 2240}{6 \times 29000000 \times 17{\cdot}458} = {\cdot}1854 \text{ inches.}$$

By equation 4 $\quad W : W_1 :: G^{\frac{3}{2}} : G_1^{\frac{3}{2}}$

or, in the case of beam A, a,

$$\frac{W}{W_1} = \frac{9{\cdot}311}{1{\cdot}164}\ ;\ \frac{G^{\frac{3}{2}}}{G_1^{\frac{3}{2}}} = \frac{22^{\frac{3}{2}}}{5{\cdot}5^{\frac{3}{2}}}$$

$$\text{or } 1{\cdot}164 \times 22^{\frac{3}{2}} = 9{\cdot}311 \times 5{\cdot}5^{\frac{3}{2}}$$

$$120{\cdot}1 = 120{\cdot}1$$

And by equation 5

$$V = \frac{V_1 \sqrt{G_1}}{l_1^3} \times \frac{l^3}{\sqrt{G}} = \frac{\cdot 1854 \times \sqrt{5\cdot 5}}{10^3} \times \frac{10^3}{\sqrt{22}} = \cdot 09269 \text{ inches},$$

being the same as when found in terms of I.

21.—By obvious induction from the foregoing, the ratio of the deflection of any two similar rails of equal length is the reciprocal of the cube root of the ratio of their moments of resistance.

Thus in the case of the two beams A, *a*,

$$\frac{V}{V_1} = \frac{1}{\sqrt[3]{\frac{W}{W_1}}} \text{ or } \frac{\cdot 09269}{\cdot 1854} = \frac{1}{\sqrt[3]{\frac{9\cdot 3111}{1\cdot 164}}} \qquad (6)$$

$$\text{or } \cdot 4999 = \cdot 4999.$$

22.—It thus appears that in similar beams of equal lengths the relations of transverse strength (*i.e.* the ratios of the moments of resistance) are as the cubes of the square roots of the respective sectional areas, and the deflections (at points of greatest stress) inversely as the square roots of these areas.

23.—In experiments on rectangular bars (such as those made by Professor Hodgkinson and by the Commissioners on the Application of Iron to Railway Structures, in 1847), the ratio of transverse strength of bars with similar sections was determined by the ratio of the product of the breadth by square of depth of their respective sections. The ratio thus found is obviously the same as $\frac{G^{\frac{3}{2}}}{G_1^{\frac{3}{2}}}$; but since the mean breadth and depth of beams with sections such as those of railway bars is not easily found, I would suggest substituting this ratio of the areas, or of the weights of a yard run—the assumption in either case being that the beams are of the same material, and nearly mathematically similar in shape.

24.—I make this suggestion since (although founded on most elementary mathematical reasoning) these relations of the area to the transverse strength in similar beams do not appear to be generally known.

25.—Thus, in the table of experiments already referred to in Vol. XXV. of Proceedings of Civil Engineers, a column is given headed "Ultimate strain per square inch," obtained simply by dividing the ultimate strain by the sectional area. Now, this column is, I venture to think, misleading, if used for computing the comparative strength of the materials under trial; and that it is so used, is evident from the lecturer's own statements, which passed unchallenged in the subsequent discussion (see pp. 375-377, Vol. XXV. of Proceedings).

26.—In Table 2, attached to this paper, column 4, is an extract from the column referred to, giving the so-called "ultimate strain per square inch" of seven steel rails. Column 6 gives also the coefficient of strength (C) obtained, as stated in paragraph 15. Now, by column 4, the strongest iron appears to be rail *a*, whereas by column 6 the strongest is *e*; the nearest to mean strength by column 4 is D, and by column 6 is *a*. A and D, the materials of which appear of exactly the same strength according to column 6, are of very different strength according to column 4, &c., &c.

Of course, had the trial been one of tensile strength merely, instead of transverse strength, then column 4 would correctly express the relative strength of material.

27.—Table No. I provides only for finding the *working* loads of similar rails and their corresponding deflections. It would be more complete were another column added showing the coefficient in each case for finding the load to produce a given deflection in similar rails. This may, however, be easily found from the data already given.

28.—Thus by formula for deflection

$$V = \frac{W \times l^3 . n''' \times 2240 \times 12^3}{8\,E\,I} = \cdot 00278\,\frac{W\,l^3}{I} \quad \left\{ \begin{array}{ll} W = & \text{working load in centre when supported at both ends.} \\ l = & \text{length in feet.} \\ n''' = & \frac{1}{6} \\ E = & 29000000 \\ I = & \text{moment of inertia.} \end{array} \right.$$

$$\text{Therefore } \frac{W}{V} = \frac{I}{\cdot 00278\, l^3}$$

$$\left.\begin{array}{rl} \text{Take } W_1 = & \text{working load} \\ I_1 = & \text{moment of inertia} \\ \text{and } V_1 = & \text{deflection} \end{array}\right\} \text{of any other rail.}$$

$$\text{Then } \frac{W_1}{V_1} = \frac{I_1}{\cdot 00278\, l^3}$$

and dividing former equations by this

$$\frac{W}{V} \times \frac{V_1}{W_1} = \frac{I}{I_1} \text{ ; or if } V = V_1$$

$$\frac{W}{W_1} = \frac{I}{I_1}$$

If the rails are similar, then $\frac{I}{I_1} = \frac{G^2}{G_1^2}$ (equation 2, par. 12) and

$$\frac{W}{W_1} = \frac{G^2}{G_1^2} \qquad (7.)$$

29.—Thus in any beams of equal lengths, the weights producing equal deflections are as the moments of inertia; in *similar* beams, as the squares of the sectional areas.

Ex.—In the two similar beams A, *a*, required the weights (in centre as before) to produce a deflection of $\frac{1}{480}$ the length of 10 feet.

$$\text{In A} \qquad W = \frac{V\,I}{\cdot 00278\, l^3} = \frac{\cdot 25 \times 279 \cdot 33}{\cdot 00278 \times 10^3} = 25 \cdot 12 \text{ tons}$$

In *a* By equation 7 :— $W_1 = \frac{G_1^2}{G^2} \cdot W = \frac{5 \cdot 5^2}{22^2} \times 25 \cdot 12 = 1 \cdot 57$ tons ;

or by formula for deflection

$$W_1 = \frac{V\ I_1}{\cdot 00278\ l^3} = \frac{\cdot 25 \times 17 \cdot 458}{\cdot 00278 \times 10^3} = 1 \cdot 57 \text{ tons.}$$

Both methods thus giving the same result.

30.—Of course the converse holds true, that with equal weights the deflections are inversely as the moments of inertia, or, in similar beams, inversely as the squares of the sectional areas.

31.—In practice it may be found difficult to decide which of the examples given in Table I. is most similar to the rail whose strength and deflection it is required to find. The following rule, resulting from the foregoing, will therefore be found useful.

32.—Take the largest sectional dimension obtainable, call it d, and the corresponding one of the given rail d_1;

Call G the weight of the rail required.

G_1 the weight of the rail given.

Then with similar beams $\frac{G}{G_1}{}^* = \frac{d^2}{d_1^2}$

If dissimilar $\frac{G}{G_1} \lessgtr \frac{d^2}{d_1^2}{}^\dagger$

Col. 9, Table I gives the index of similarity of the different rails $\frac{G_1}{d_1^2}$

G. G.

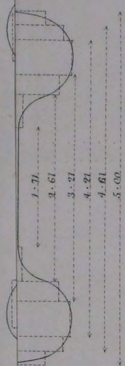
* If m be the common ratio of dimensions as assumed in paragraph 12, then $\frac{d^2}{d_1^2} = m^2 = \frac{G}{G_1}$ (by equation 1.)

† Since (in similar beams) $\frac{G}{G_1} = \frac{d^2}{d_1^2}$ then $\frac{W}{W_1} = \frac{G^{\frac{3}{2}}}{G_1^{\frac{3}{2}}} = \frac{d^3}{d_1^3} = \left(\frac{G^{\frac{3}{2}}}{G_1^{\frac{3}{2}}}\right)^2 \times \frac{d_1^3}{d^3} = \frac{G^3\ d_1{}^3}{G_1^3\ d^3}$

This equation will be found to give good approximate results for beams having a slight dissimilarity, as shewn in examples below. It may, of course, be reduced, by dividing the fraction by the equivalent quantities $\frac{G}{G_1}$ and $\frac{d^2}{d_1^2}$: thus $\frac{G^3 \times d_1^3 \times \frac{G_1}{G}}{G_1^3 \times d^3 \times \frac{d_1^2}{d^2}} = \frac{G^2 \times d_1}{G_1^2 \times d} = \frac{W}{W_1}$ which is correct in similar beams, but less accurate than the first when there is dissimilarity, *i.e.* when $\frac{G}{G_1} \lessgtr \frac{d^2}{d_1^2}$

NO

ILWAY.



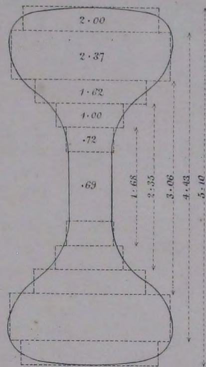
Sectio

Wei square ins.

70·99 lbs.

No. 5.

BESSEMER STEEL RAIL, LONDON & NORTH WESTERN RAILWAY.



Sectional Area 7·586 square ins.

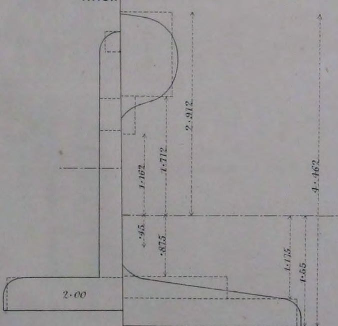
Weight per Yard 76·46 lbs.

I = 22·208.

IL,

TENSION.

IRISH



Section

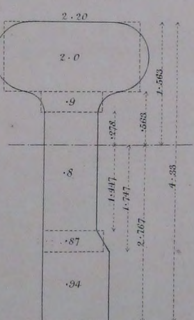
Wei square ins.

·362 lbs.

2.

No. 17.

SINGLE HEADED RAIL, AUSTRIA.



Sectional Area 4·856 square ins.

Weight per Yard 48·948 lbs.

I = 8·92.

Kell, Bros. Lith. Castle St. Holborn.

TABLE I.

1	2	3	4	5	6	7	8	9	10	11	
							Deflection for length of 10 feet. Weight on centre (W in Col. 6.)		Weight uniformly distributed (2 W).		
Reference and Description.	Weight per yard run in pounds. G	Depth of rail in inches. d	Calculated moments of Inertia. I	Index of similarity, being value of $\frac{G}{d^2}$	Working load on centre, with length of 10 feet, supported at both ends, in tons. W	Co-efficient of expression $\frac{G^{\frac{3}{2}}}{l}$, l being length in feet $\left(W = c \times \frac{G^{\frac{3}{2}}}{l}\right)$ C	Calculated by formula $V = \frac{W n''' l^3 \times 12^3}{8 E I} = \cdot 00278 \frac{W l^3}{I}$ inches.	Co-efficient $\left(V_1 \frac{\sqrt{G_1}}{l_1{}^3}\right)$ l being in feet. D	Calculated by formula $V = \frac{W n''' l^3 \times 12^3}{8 E I}$ inches.	Co-efficient of $\frac{l^3}{\sqrt{G}}$ 1·25 D	REMARKS.
1 Double-headed rail......	73·543	5·10	21·113	2·82	1·35	·0214	·1776	·00152	·222	·0019	
2 ditto ...	80·430	5·25	23· 56	2·91	1·49	·0206	·1758	·00157	·2107	·00197	
3 ditto ...	70·963	5·00	19· 58	2·83	1·302	·0217	·1844	·00155	·2305	·00194	
4 ditto ...	83·019	5·43	26· 88	2·81	1·65	·0218	·1706	·00155	·2132	·00194	
5 ditto ...	76·460	5·10	22·208	2·93	*1·4	·0209	·1752	·00153	·2190	·00191	* Nos. 5 and 13 being of steel, W may be doubled.
6 Bridge rail	82·454	4·00	14·711	5·15	1·25	·01669	·2363	·00214	·2954	·00267	
7 ditto ...	69·590	3·03	5·634	7·58	·601	·0103	·2964	·00247	·3705	·00309	
8 ditto ...	14·030	1·19	·185	9·8	·059	·0112	·8912	·00334	1·114	·00417	
9 Flange..	25·430	2·29	1·556	4·87	·195	·0151	·3483	·00175	·4353	·00219	Nos. 8, 9, and 10 are small rails for Contractors' tramways.
10 Barlow's	12·770	1·37	·211	6·6	·041	·009	·5403	·00193	·6754	·00241	
11 Flange..	76·205	4·9	18·905	3·17	1·34	·0201	·1971	·00172	·2463	·00215	
12 ditto ...	66·990	3·54	9·362	5·35	·823	·015	·2444	·00 20	·3055	·0025	Nos. 14, 15, and 17 are taken from Austrian Manual.
13 ditto ...	73·362	4·46	22·392	3·7	*1·281	·0204	·1590	·00136	·1987	·00170	
14 ditto ...	65·880	4·26	14·529	3·6	1·121	·0214	·2145	·00174	·2681	·00217	By German formula, value of W is as follows :—
15 ditto ..	63·927	2·76	10·245	4·5	·79	·01545	·2144	·00171	·2680	·00214	
16 ditto ...	71·144	5·07	22·741	2·7	1·553	·0258	·1899	·00160	·2374	·0020	(14). W = 1·027 tons.
17 Single-headed..	48·948	4·33	8·920	2·61	·951	·0277	·2964	·00207	·3705	·00529	(15). W = ·626 tons. (17). W = ·7 tons.

TABLE II.

Abstract of Experiments on Steel Rails, extracted from Tables Vol. XXV., P.C.E.

1	2	3	4	5	6	
Reference.	Description.	Ultimate strain. Total lbs.	Ultimate strain. Per square inch lbs. *	Area in square inches.	Coefficient of $\frac{G^{\frac{3}{2}}}{L}$ for strength. C	REMARKS.
A	Crewe, 1866 (new).........	80176	10453	7·67	·0439	$C = \frac{W_1 \, l_1}{G_1^{\frac{3}{2}}}$
D	Cammell & Co., 1864 (new)	71536	10061	7·11	·0439	here
G	S. Fox & Co., 1864 (new)..	57400	8504	6·75	·0381	$W_1 = \frac{\text{Ultimate strain}}{\text{Factor of safety } (= 6)}$
						$l_1 = 5$ feet.
a	S. Fox & Co., 1863	88736	10476	8·47	0·419	$G^{\frac{3}{2}} = (\text{Sectl. area} \times 10{\cdot}08)^{\frac{3}{2}}$
c	Ditto ditto	77744	9178	8·47	·0367	
d	Lancashire Steel Co., 1865	78096	10195	7·66	·0429	These specimens are all double-headed rails.
e	Ditto ditto	73248	10434	7·02	·0458	
	Means of above	75276	9900	7·59	·0418	* Col. 4 is obtained by dividing Col. 3 by Col. 5, and is not the *real* strain per square inch.

PAPER XI.

DETAILS CONNECTED WITH THE SERVICE OF HEAVY MUZZLE-LOADING RIFLED GUNS.

The following Paper, which has reference to details connected with the service of heavy muzzle-loading rifle guns in open batteries, has already been published in the " Proceedings of the Royal Artillery Institution." In inserting it in the Royal Engineer Corps Papers, an addition of two plates has been made, viz., Plate VI, showing a portion of an open battery with iron shields. Plate VII, a portion of a casemated battery, including all the accessories and arrangements for passing up ammunition to the gun floor. The necessary explanations are given upon these plates.

15th November, 1870. W. F. D. J.

Proceedings of a meeting assembled at 109, Victoria Street, on the 30th of July, 1866,

PRESENT:

Major Gen. ST. GEORGE, C.B., R.A.	Brig. General LEFROY, R.A.
Major Gen. A. G. TAYLOR, R A.	Colonel GAMBIER, C.B., R.A.

Lieut. Colonel JERVOIS, C.B., R.E.

" Major General Taylor read some remarks he had drawn up as Inspector General of Artillery, the result of his observations in making his inspections. These are appended to the proceedings.

" The meeting considered the general principles to be adopted in the future construction of forts and coast batteries, and decided on the following :—

1.—" The Southsea auxiliary defences, as lately constructed, with respect to the arrangements of the magazines, expense magazines, shell rooms, &c., as shewn in the plan of that work laid before the meeting, are generally approved, and may be taken as a satisfactory general guide for future constructions. (Plate I).*

2.—" The expense magazines as shewn in this plan, viz. one for every four guns, are concurred in. Each magazine should contain at least twenty-five rounds per gun; that proportion being increased for such faces as are likely to be long under fire, or where the main magazine is unavoidably more remote from the expense magazines than in this plan.

* On account of insufficiency of space, only a portion of the plan is given. A diagram has been introduced to explain the relative positions of the guns, the store rooms, and ammunition chambers.

3.—" A plan embodying these general principles will be prepared, and the shell-filling rooms and room for filling cartridges will be shewn upon it.

4.—" Colonel Jervois, R.E., placed before the meeting a proposed method of moving shells for casemates and for open batteries, which was generally approved; to be considered in detail.

5.—" He also shewed a plan of transferring the cartridges from the magazine to the gun floor; on which it was observed that it will be preferable in all cases to bring up the shell at the nearest opening to the gun,* and the cartridge at the more remote one. The details will be further considered.

6.—" Drawings in detail of artillery small stores, general stores, shell stores, side-arm stores, &c., will be prepared for consideration.

7.—" The meeting consider that, when practicable, no work should be dependent on one magazine alone for its supply of powder.

" Particular attention should be given to the effective lighting of all magazines.

8.—" A recognized nomenclature for every description of accommodation and arrangement should be adopted, and not departed from.

9.—" The side arms in casemates should be ranged along the interior of the arch.

" Having laid down the above general principles, the meeting adjourned for the present, to give time for the preparation of plans in accordance with them, and for further consideration of the general subject."

The Committee met again and considered the plans on 7th February, 1867. They were then carried out.

The accompanying questions, embodying the principal points which most nearly affect artillery defence, were drawn up in connection with the foregoing discussion, and are here inserted as a help to the consideration of this subject by officers who may be called on to report upon it hereafter :—

(1) *Magazines.*—Is the communication between the guns and the expense magazines sufficiently direct and as well covered as circumstances permit ?

(2) Are the expense magazines in the best situations in point of security, and convenient in point of access?

(3) Are the main magazines in the best situation in point of security, and convenient in point of access ? Is the store of powder sufficiently divided to render all risks as small as is practicable ?

(4) Are the doors or openings in the best direction, in reference to security under fire ?

(5) Are the shell rooms and shell recesses sufficiently numerous, convenient of access, and convenient for the supply of loaded shells with rapidity ?

(6) *Number of Artillery Store Rooms.*—Are they adequate in point of accommodation and size; sufficiently numerous; conveniently placed ?

(7) *Traversing Platforms.*—Are the racers firmly laid and true in gauge ? Do the guns traverse with the proper degree of facility ?

* It was subsequently explained by Colonel Jervois, that the bringing up of the shell through a lift, placed immediately behind the merlon between two guns in a casemated battery, would be attended with disadvantage, as the traversing racks or tackle would lie across the mouth of the lift.

(8) Are the *ground platforms* in good repair, at the proper slope, and of sufficient size for the guns now mounted upon them?

(9) Are *traverses* sufficiently numerous, and do they give as much protection as the circumstances of the work admit of?

(10) *Splinter-proof Cover.*—Is there any protection provided against splinters of shells? Is there in your opinion room for its extension or improvement?

(11) *Cover generally.*—Are the parapets of the batteries high enough and solid enough to give a serviceable degree of protection?

(12) *Aids to accuracy.*—Are the heights of each battery, and the distances of conspicuous permanent objects within cannon shot of it, perfectly ascertained and permanently recorded at the battery?

The Committee above referred to having agreed on general principles, the subjoined memorandum was drawn up by the Deputy Director of Works, and embodies the instructions under which the officers of that Department acted in completing the works at Southsea Castle:—

Southsea 14/444 1.—"The amount of cartridges and loaded shells that it is proposed to provide accommodation for in batteries is 100 rounds* (100 per gun).

2.—"The supply of cartridges provided for the guns, together with the proportion of powder in bulk (if any), and bursting charges for the shell, should be stored in the main magazines, and no portion should be stored (except under extraordinary circumstances), in the expense magazines, which are intended only for temporary use, when the battery is put in a state of preparation for action

3.—"The expense magazines situated in proximity to the main magazines, are intended to accommodate, under these circumstances, twenty-five cartridges for each of the guns to which they are allotted (usually for four guns).

4.—"The expense magazines that cannot easily be replenished from the main magazines (as for instance those in the flanks at Southsea batteries), should receive not less than thirty cartridges per gun.

5.—"The shells when loaded should be stored in the expense and main shell stores.

"If supplied unloaded, they should be stacked in the interior of the battery.

"Of the loaded shells supplied, a number equivalent to the cartridges destined for the expense magazines, should be stored in the expense shell stores.

6.—"The remainder of the 100 shells per gun should, when supplied loaded, be stored in the main shell stores.

7.—"The different natures of cartridges should be kept sufficiently distinct to prevent confusion. With this object, the bays in the magazines have been subdivided. The cartridges are packed in zinc cylinders, and can be piled to the extent of ten in height in the case of cartridges for 9-inch guns, and of guns of

* This number was fixed at a time when it was considered that shells would be used on all occasions. As now laid down in Circular on Ammunition and Stores—Garrison Service, the proportion of shells will be 65. The rest of the 100 are solid shot. Of these, some will be stored near to the gun, and the rest piled in a covenient place.

less calibre. Seven layers will, however, in general be found sufficient, and taking into account the extent of floor space allowed for the stacks, will be found to afford the necessary accommodation.

8.—" The shells of 9-inch rifled guns, and of guns of greater calibre, should be made to stand on their bases in the shell stores. Smaller shells can be stacked.

" Owing to the great length of the service shells for 9-inch and 12-inch guns, no economy of space arises from stacking being resorted to, more particularly as the stacks of shells when thus arranged have to be kept well apart, and a free space provided for access to them. The labour of moving the shells from the store when in stacks, will also prove to be much greater, even with the assistance of machinery, than when the shells are made to stand on their bases.

" A traveller having been supplied for one of the main shell stores at Southsea, a comparative trial of the merits of the two plans can be instituted.

Artillery Stores.

9.—" Of all the artillery stores supplied for use in a battery, the side-arms, levers, tackle, and handspikes require least protection from the weather, and can be stored in light metal buildings.

" The approved method of storing them is to have them all under the same roof. One example of this kind of stores has been provided at Southsea. The other sheds provided for the side-arms and tackle were constructed before this method was adopted.

10.—" It is intended that the side-arms and tackle for each gun should be kept quite distinct, so that they can be readily removed, and taken to the gun for whose service they are required.

" Each division of the side-arm rack is intended for the side-arms of two guns; the distinction between the two sets is maintained by the heads of those for one gun being at one end, and the heads of the second set being made to project at the other end.

11.—" The 'artillery small-store buildings' are intended for the small stores *in use*.

" The principle of arrangement is that of separating the sets required for each gun. The plans of the artillery small stores furnished for the Southsea batteries, explain the proposed method of storing these articles.

12.—" The 'artillery general store' is intended to take the *duplicate or spare stores*, tackle, and side-arms, &c., that are provided for the guns, and that are under the charge of a master-gunner.

" No particular arrangement, beyond that necessary to ensure economy of space, is in this case necessary.

" W. F. D. J."

October 12th, 1868.

The batteries were not fully armed before May, 1869, when they had mounted :—

1 Shunt rifled 13·3-inch gun of 22 tons (the original BIG WILL. of 1863).
22 Woolwich rifled 9-inch guns of 12 tons.
9 Woolwich rifled 7-inch guns of 7 tons.

The general artillery store, the small arm store, and the side arm sheds were not finally completed, but were handed over temporarily. At this stage it was decided by the Secretary of State that the Commanding officers of Artillery and Engineers, with an officer from the School of Gunnery, and one from the Department of Works, should report on the arrangements, which was done in July, 1869, and resulted in the subjoined report. Appreciating the great importance of diffusing throughout both branches of the service the best information on these subjects, the Secretary of State has sanctioned its publication.

J. H. L.

November 10th, 1869.

Correspondence in respect to the examination and trial of the Side-arm Store, Artillery Small and General Store, Expense Shell Store, and Magazines, in the Batteries at Southsea Castle, armed with 13-inch, 9-inch, and 7-inch, Muzzle-Loading Rifled Guns, by a Committee of Officers of Royal Artillery and Royal Engineers.

COMMITTEE.

Portsmouth 5/2870. Captain and Brevet Major W. J. GRIMSTON, R.A.
Captain E. HARDING STEWARD, R.E.
16 July, 1869. Captain J. E. BLACKWELL, R.A.
Lieut. J. DU T. BOGLE, R.E.

Side-Arm Store.

"A store containing the side-arms, block-tackle bearers, buckets, wads, &c. for *twelve* guns was examined; also tried with the full number of men requisite to man that number of guns.

"The fitments and their arrangements appear well adapted for the purposes required. It is, however, suggested that in future this class of store should be constructed to contain the stores of eight guns only; for when the numbers of the twelve guns went for their stores, the crowding of the men at the doors was at first too great to permit of the speedy removal of the stores. It is also suggested that the doors should be made broader, that the tackle brackets be made 12 inches long, and of round instead of flat iron, and that pegs be added for the buckets. (Plate II. figs. 1, 2, 3).

Artillery "Small" Store.

"A store for the small stores (in use) for twelve guns was examined and tried. It is suggested that in future this class of store should be made to take the small stores for *eight* guns only, in order that it may correspond with side-arm store, if reduced as proposed.

"It is also suggested that the divisions be marked on the bench by black lines, in order that the spaces devoted to the stores for each gun should be more apparent.

"It is also recommended that the 'preventor' rope should be classed with the small stores, and provided for accordingly; on account of the number of the gun detachment that procures it having also to get the sights. The store examined contains the small stores for five 7-inch guns and seven 9-inch guns. It is suggested that, where possible, the accommodation of the small stores of guns of different calibres in the same building, should be avoided. (Plate II. figs. 4, 5, 6.)*

General Artillery Store.

"A building for the reception of the spare or general stores for twenty-four guns was next examined.

"It is recommended that a few additional tackle brackets should be introduced and a short ladder provided, to enable the men to reach the top of the racks. (Plate III. figs. 1, 2, 3.)

Expense Shell Store.

"An expense shell store for four guns was examined, and the service of shell from it tried. (Plate IV. figs. 1, 2.)

"It was found to be capable of containing twenty-five shells for each of the four guns. It is, however, suggested that, in future, expense shell stores should not supply more than two guns, the reduction being proposed with the view of diminishing the confusion and delay that must necessarily arise when the numbers from four detachments come for shell at the same time.

"It is also suggested that a lobby should be provided in connection with an expense shell store, in which shells can be fuzed if necessary. With reference to the issue of shell from the lobby, it is recommended that a shell hatch at the level of the terreplein (provided on each side of the lobby), should be used for the delivery of the shell, shot rails being employed for the transit of the shell from the mouth of the hatch to the gun.

"It is for consideration whether, at the expense shell stores at Southsea, the shell might not be raised by tackle at the door, and placed on shot-rails laid at the level of the terreplein, and be slid to the gun, in preference to employing trucks for their removal; as the latter cannot be worked without planking, on account of the looseness of the gravel. (Plate IV. figs. 3, 4.)

* The pegs *a* on Fig. 6 are in a position suitable for the cylinders of the 12 and 7-ton guns, but not for those of the 18, 25, and 35-ton guns. In preparing fittings for the reception of the small stores of these guns, it will be necessary to lower the shelf to which the pegs *a a* are attached, to within 12 inches of the bench (omitting the cylinder pegs and the hooks *c c*) and to place an additional shelf 21 inches above the bench. This shelf should be 16 inches broad, and should be furnished with small hooks along the front edge. The object of this shelf is to take the two cartridge cylinders for each gun. Where the wall against which the bench and shelves are placed will not admit of a free height of 3 feet above the top shelf (the cylinder for the 12-inch gun being 28 inches high, exclusive of handle) arrangements must be made for hanging the cylinders from the roof.—

W. F. D. J.

" The expense shell store on the right flank of the west battery, which is provided with a ledge and rails in lieu of a ramp, and a small traveller with blocks and tackle for raising the shell to the ledge, was next examined.

" Suggested, that shot rails should be employed in other and similar cases in lieu of the ledge, as they will probably prove as efficient, and more economical.

" The patent unlocking differential pulley, also the tackle and small metal blocks for raising the shell, were tried. Some experience appears to be requisite to enable a man to use the differential pulley properly, and without which an accident might occur. The preference is therefore to be given to the blocks and tackle for employment with the small traveller.

" The metal clips for holding and raising the shell were tried, also a rope strap (selvagee), to effect the same object. The latter proved to be easier of application and quite as effective as the two clips, and is therefore preferred.

Expense Magazine.

" An expense magazine for the service of four guns was examined. (Plate V. figs. 1, 2).

" The chamber appears capable of containing conveniently the expense ammunition for four guns, and the bays afford the requisite separation of the two natures of ammunition.

" With the view of facilitating the service of ammunition to guns, it is recommended that the number of guns to be supplied by an expense magazine should be reduced from four to two.

" It is suggested also that the separation between the lobby and the magazine should be of brickwork. That the rack to take the cylinders should be placed in the middle of the chamber, with a passage (and door leading thereto), on each side ; in order that the cartridges may be delivered to both guns simultaneously,* and that the necessity for removing the zinc cylinders, when emptied, may be avoided. (Plate V. figs. 3, 4).

" It is also suggested that the doors of the chamber containing the cartridges should be made in half, the lower half being employed as a ledge for the cartridge when being issued.

Main Shell Store.

" The main shell stores were examined, also the traveller for stacking shells. It appears that the system of storing loaded shells on their bases is the preferable one, that the traveller works well, and that there can be no objection to the system of stacking proposed, in situations where piling is necessary. It is suggested that for transferring shell from a main store to the expense shell

* This arrangement necessitates an undue length for the chamber. The arrangement was put forward under the impression that the issuing of cartridges to the men of the gun detachments would take place inside the serving room. In practice these men would not be allowed to enter the serving chamber, and all issues would be made through the upper half of the outer door of the serving room. This door should therefore be made a hatch door, as well as the door of the magazine.—W. F. D. J.

store, shot rails should be experimented with, and a further report made. It is considered that the rails will be found to offer greater facilities for the removal of heavy shell than trucks or carts, on gravel, and will probably prove more economical and as effective as a tramway, and much more easily laid and repaired.

"It is recommended that 400 feet (about) of shot rails, and a proportion of curved rails, should be supplied to the Royal Artillery at Southsea Castle, in order to test this matter.

Shell-filling Room.

"It is understood that a shell-filling room is to be constructed on the space near the entrance to the castle. As this site, though central for the battery, is far removed from the main shell store, it is suggested that a filling room should be provided contiguous to each range of main shell stores, and so situated that the empty shells can be stacked with convenience in its immediate vicinity.

Main Magazine.

"The main magazine of the west battery was examined. The fittings appear to be suitable. It is suggested that the shifting room should not be in the same block as the magazines.

"It is for consideration whether a cartridge-filling-and-shifting room should not be constructed on a site separated from the magazine, but conveniently near to it.

(Signed) "W. J. GRIMSTON, Capt. and Bt.-Major, R.A.
"E. HARDING STEWARD, Captain R.E.
"J. E. BLACKWELL, Captain R.A.
"J. DU T. BOGLE, Lieut. R.E."

30 July, 1869. Colonel Wodehouse, C.B., Commanding Royal Artillery, and Colonel Hadden, Commanding Royal Engineer, in forwarding the above, concur in the same, with the following additions and exceptions:—

"Recommended, that a side-arm shed for each of the 23-ton guns should be constructed under the parapet, close to the guns.

"Emplacement for one gun only at present made."

Remarks made by Col. Jervois, C.B., Deputy Director of Works:—

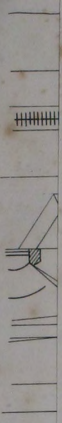
"This was intended to be done."

Expense Shell Store.

"That a hatch for the issue of shells for the 13-inch guns be constructed in the wall of expense shell rooms, with lifts, shot rails, &c.

Ditto.

"Cunningham's gear is applied to the gun in question, and the chain will prevent the shell being brought up on rails nearer than the end of the platform."



"Shot rails to be flush with the ground and carried round the muzzle and back to the starting point, crossing the racers, a gap being left wide enough for traversing."

"The supply of shot rails was suggested with a view of testing the practicability of this proposition in the case of guns worked by tackle."

"In regard to par. 2, page 8, the Commanding Royal Engineer states that the gravel will, if rolled, consolidate and render the tackle unnecessary."

"If chalk is added, and the gravel well rolled, the surface will be much improved, but not sufficiently so to dispense with shot rails or planking."

"Adverting to the suggestion for shot rails, the Commanding Royal Engineer states that any alteration required can be effected by his Department, and that he does not concur in the issue of rails to the Royal Artillery as necessary.'"

20 Aug., 1869. Major General Lefroy, in transmitting the foregoing to the Deputy Director of Works, observed that the substantial suggestions of this report, in which he concurred, were:—

1.—That twelve guns are too many to be supplied from one side-arm store: eight should be the limit.

2.—That the same remark applies to the artillery small store.

3.—That, if possible, the stores of 7-inch and 9-inch guns should not be mixed in the same sheds.

4.—That there should, if possible, be an expense shell store to every two guns instead of four.

5.—And an expense magazine in the same proportion.

He added:—

"There are also a number of minor suggestions of a practical character, for improving the several stores and facilitating the service of the guns.

"I do not see why the Royal Artillery should not be supplied with 400 feet of shot rail as asked for, although the Commanding Royal Engineer seems to prefer to manage it for them. The officers serving the guns appear to me the most likely persons to discover by trial where shot rails can be used with the greatest convenience and economy of labour.

"The report of the committee referred to on $\overline{4874}$, and this report, are documents of so much practical value, that I think they should be printed, or communicated to the Royal Engineer Corps Papers and Royal Artillery Institution 'Proceedings' for general information."

Deputy Director of Works to Director General of Ordnance.

2 Sept., 1869. 1.—"I concur in the adoption in future of the suggestions contained in the report.

2.—"Plans of the several store buildings and fitments, revised in accordance with the suggestions, are now being made.

3.—"At the Southsea batteries, the slight deficiencies in the fitments of the stores and ammunition chambers will be made good.

4.—"Other additions, such as the laboratory and shifting room, and the shell-filling rooms, were always intended to be made, when funds are voted for the purpose.

5.—"As regards the shot rails, no doubt those which are *moveable* should be supplied to the Royal Artillery, and laid and used by them where required. Some rails, however, (at the doors of the expense shell stores for instance), will be fixtures, and these will be provided and fixed by the Royal Engineer Department.

6.—"It appears most important that there should be a full trial of the shot rails, and I am at present having a drawing made of rails, both straight and curved, adapted for the movement of *elongated* 9-inch shells.

7.—"With regard to the last paragraph of your minute, the two papers you mention might be circulated with advantage, as you propose."

25 Oct., 1869. Deputy Adjutant General, R.A., to Director General of Ordnance, states that he concurs with him and the Deputy Director of Works, and would propose that the reports be printed for circulation.

27 Oct., 1869. Major General Lefroy forwards to Lord Northbrook for approval, the proposal for transmitting copies to the editors of the "Proceedings" of the Royal Artillery Institution, and Corps Papers, Royal Engineers, as a ready way of giving publicity to this report; and this was approved by the Secretary of State for War.

PAPER XII.

IRON SHIELD EXPERIMENTS.

By Lieut.-Col. INGLIS, R.E.

At the conclusion of Paper XIII, Volume XVIII, it was intimated that an experimental Gun Shield, embodying all the latest improvements, would probably be tried at Shoeburyness early in the year 1870. The present Paper gives an account of this trial.

The construction of the Shield is shown in Plate I, and it may be described in the words of a Paper printed by order of the Director of Works, dated Fortification Branch, War Office, 23rd February, 1870, as follows:—

"It is 12 feet long, and 8 feet 2 inches high, and is adapted for use in a masonry casemate having an opening of those dimensions covered with a flat arch, as at Hurst Castle and other works. The same construction, slightly modified, will apply to those instances of masonry casemates where the arch over the opening is curved; it will also be applicable, if required, to open batteries.

"The shield is composed of two main parts, namely, the armour and the supports.

"The armour consists of three 5-inch plates, made to the full size of the shield by a process recently adopted in the fortification branch, with intervals of 5 inches between them, in which a concrete composed of iron turnings and tar mixed hot, and weighing about 240 lbs. per foot cube, is introduced.

"This arrangement of armour is the result of experiments which took place on the 4th February, and 4th and 14th June, 1869,* with small targets designed by the officers of Royal Engineers engaged on iron fortifications, as well as of other investigations by the same officers. The front plate is bolted to the second by means of ten 3-inch armour bolts with plus threads ($5\frac{1}{2}$ threads to the inch) and spherical nuts at each end, seated in corresponding holes in the armour plates. The second and third armour plates are held back to the supports by eight bolts of similar pattern. These bolts, however, are secured to the skin of the supports by means of spherical nuts in coiled washers of special construction, similar to those used in the two small targets above referred to. The fastenings are so laid out, that in no case does an armour bolt appear at the back of the shield.

* See pages 268 to 270, and 271 to 273, Vol. XVIII.

"The port opening in the front armour measures 4 feet high, and 2 feet 6 inches wide, and admits of the 10-inch 18-ton gun training 70°, elevating 10°, and depressing 5°. The 12-inch 25-ton gun would train 60° behind the shield, elevate 8°, and depress 5°.

"The iron concrete round the port in both intervals is retained by means of frames composed of 1-inch plate and angle irons, so disposed as to admit of their being compressed between the armour without seriously straining the plates.

"The supporting structure is composed of 1-inch plate, and 6-inch by 6-inch by 1-inch angle irons, built in the form of a case, to cover the whole of the back of the armour except in the central space required for the working of the gun.

"The depth or thickness of this case is 2 feet 6 inches. It stands upon a 1½-inch base-plate, the ends of which pass under the piers of the masonry structure in which the shield is fixed.

"The whole of the case is filled with iron concrete.

"The shield is held down by means of 2-inch bolts to a 3-inch plate, bedded in the foundation, at a depth of about 2 feet below the floor level. The ends of this plate pass under the masonry piers. Three of the holding down bolts are nutted on the top side of the base plate inside the case; the remainder are bent over four 3½-inch studs which pass through the rear armour plate and the front skin of the case.

"In addition to the armour bolts, already described, there are two 3½-inch studs passing through the rear armour plate and skin near the top of the shield to relieve the fastenings in that part from shearing.

"The weight of the shield is approximately as follows :—

	Tons	cwt.
Armour plates	22	10
Bolts and nuts	0	18
Supporting structure and port frames ..	12	2
	35	10
Iron concrete	20	18

"The masonry in which the shield stands, is built to represent a portion of the adjacent work of a masonry fort prepared to receive iron shields.

"The parts immediately about the shield are composed of stone; brickwork in Portland cement being used for the remainder. To make up, in a small degree, for the absence of mass in this work, as well as for its being quite fresh and of a temporary character, it is held together and strutted by means of timber and tie bolts. The top is also loaded with old armour, to give weight, corresponding, in some measure, with the weight of the upper part of an actual work."

The shield was made at the Atlas Works, Sheffield, under the inspection of the officers of the Fortification Branch. It was completed at the works in about thirteen weeks from the date of order to commence. The contract for it required that the materials and workmanship should answer the conditions of the specification for the ironwork of Fort Cunningham, Bermuda, which was then in hand.

Under these conditions the piece cut out of each armour-plate to form the port was subjected to the established proof at Shoeburyness.

For this proof, each piece is fitted with trunnions set in its longer edges, near one end, and these trunnions are held in holes made in two massive swinging iron bars suspended from over head. Thus, when the plate is struck it is free to turn both on its own axis, and also to revolve or swing in the suspension bars. This method of holding the plates was adopted as entailing less cost for maintenance than other plans.

The proof is carried out by firing a Palliser shot from the 7-in. muzzle-loading rifled gun at 30 yards with a 9-lb. charge. A good 5-in. plate will stop this shot, and if very good it will show only a slight star crack and bulge in rear. An indifferent plate will let the shot through, and have a large piece taken off the back. A bad plate will let the shot pass easily through, and perhaps crack a good deal, or even break in pieces. There are other appearances which weigh in assigning figures of merit to plates, and which are brought clearly to observation in this proof.

The plates of this shield gave very good results at proof, and were all three classed A-1; A being the highest of three classes, each of which has three grades.

Samples of the thinner plates and angle irons were tested in a test machine. The former broke with strains varying from 21·2 to 24 tons per square inch of sectional area in samples taken lengthways in the plates, and from 15·07 to to 18·3 tons in cross samples. The reduction of area of cross section of the samples taken lengthways, amounted to 13·5 and 19 per cent. upon the original section, and to 1·25 and 9 per cent. in cross samples.

The angle iron broke with 20·6 and 25 tons per square inch, and a reduction of about 27 per cent.

The armour bolt iron was tested under falling weights, and broke with seven blows from a ton monkey falling 30 feet, the sectional area at point of fracture being reduced 50 per cent.

The rivet iron was of special make, and broke with a reduction of area of 52 per cent. under a tensile strain of 24·81 tons.

The operation of setting up the shield at Shoeburyness occupied about seven weeks in the middle of the winter.

The casing was sent in one piece riveted together complete, except that the top plate of all and the top plate forming the sill of the opening for the port were only temporarily secured.

The two inner armour plates were first fitted to the casing, and the bolts to hold them on were carefully set in their places. The piers and upper part of the casing were then filled with iron concrete, after which the armour plates were removed, the top plate of the casing riveted on, and the casing, with the inner set of armour bolts standing out to the front, was then ready to be moved into position. This was done by hanging it on a trolly by means of the opening left in it for the port. The trolly travelled on beams supported at their ends, running at the proper level, from front to rear, through the opening in the masonry structure. As the casing was the full size of the opening, and now weighed about 20 tons, it would not have been easy to get it into position in any other way.

The three rear holding down bolts were next inserted and nutted under the lower bed plate which had been built in the foundations of the masonry structure. The lower part of the casing under the port opening was then filled with iron concrete, and the plate forming the top of this part was slid in from the front, and secured by tap-screws to the angle irons.

After this the inner armour plate was run in to its position much in the same way as the casing was, only as the opening in the armour plate was more contracted, it rode on a small traveller, temporarily constructed, and running on armour bolts for rollers. Some considerable care in adjusting the plate was necessary to make its bolt holes fit the bolts already fixed in the casing as above described. The four front double holding down bolts were then fixed and nutted under the lower bed plate, after which the concrete bed on which the shield was to stand was filled in.

The next operation was that of placing the port frame and getting in the iron concrete which was to occupy the space between the second and inner armour plates. For the latter purpose an apparatus consisting of a boiler plate skin, stiffened with angle irons, was used. This was made the full width of the shield, but less than it in height by about 5 inches, and the top of it was made in the form of a flat table standing out to the front. In vertical section it was, therefore, of this shape ┐. This skin was fitted on the armour bolts and held on by them at a distance of 5 inches from the face of the inner armour plate already in position. The iron concrete was then poured in over the top of the boiler plate skin. When cool the skin was removed, and the iron concrete with the port frame was left standing against the face of the inner armour plate.

The second armour plate, with its set of bolts standing out to the front, was next run in and nutted on to the inner set of bolts. The port frame and concrete belonging to the interval between the front and second armour plates were got in as before, and the front armour plate after them. The small spaces between the edges of the armour plates, and ends and top of the casing, and the masonry were wedged in with pieces of iron, and the shield was ready to be shot at.

The first trial took place on the 2nd March, 1870, under the superintendence of a special committee appointed for the purpose. The guns employed in the trial were as follows :—

12 in. muzzle-loading rifled gun of 25 tons.

10 in. muzzle-loading rifled gun of 18 tons.

9 in. Whitworth muzzle-loading rifled gun of $14\frac{1}{2}$ tons.

The battery was placed at 200 yards from the shield.

A programme was prepared, having for its first object a thorough trial of the shield with the largest gun. This was so far carried out, as will be seen from Table I, that the first four rounds were fired from the 25 ton gun with full battering charges.

One of these, a shot, grazed the ground before reaching the target, losing by this about 5 per cent. of its velocity, and when it did hit the target it delivered part of the blow on the masonry. Still, some very satisfactory and conclusive results were obtained from these four rounds.

A shot (Round 1721) striking half on the backed and half on the unbacked portion of the shield, was brought to a stand with its point just touching the rear armour plate. It had turned to the right, however, about 12°. There was scarcely any effect to be noticed in rear. One shell (Round 1722) struck on the backed part of the shield, and the other (Round 1724) on the unbacked part. In each instance the point made an indent 1 inch deep in the front face of the rear armour plate. That which struck the unbacked portion made a horizontal crack on the back face of the rear armour plate. That which struck on the backed portion produced little or no effect in rear. These rounds may be compared with rounds 550, 1664, and 1679, Pp. 268 to 273, Vol. XVIII.

Unfortunately the port frames retaining the concrete between the armour plates shewed early signs of weakness in the joints at the angles, and gave way at the fourth round, thus letting the concrete squeeze out during the remainder of the trial. This defect has since been remedied, and in every other respect the result of these four rounds was highly favourable to the shield.

Two rounds were next fired from the Whitworth gun, and as this was the first occasion on which the new Whitworth metal had been used in the shape of projectiles against armour at Shoeburyness, their trial was regarded with considerable interest. The exact manufacture of these shell was not clearly made known, but they were supposed to be made according to Sir Joseph Whitworth's patent process for producing steel and subjecting it to great pressure. They were stated to have different degrees of temper, but this was also left in some uncertainty. All that is known of them is that they weighed from 392 lbs. to 403 lbs ; that they were of hexagonal section, with a major diameter of nearly 9 in.; that they were from 31½ in. to 33½ in. long; and that their capacity was equal to a bursting charge of 12 lbs. of powder. For some reason, however, they were not allowed to be filled with anything but sand and sawdust on this occasion. The head of one was similar to the service pattern head for Palliser projectiles; that of the other was made flat-headed by cutting off about 3¾ inches of the pointed end.

No result of importance was obtained with the flat-fronted shell (Round 1725), as it struck just on the sill of the port, and broke up into a number of pieces.

The pointed shell (Round 1726) struck just between the backed and unbacked portions of the target, and stuck in it almost entire, with its point just touching the face of the rear armour plate, and its base projecting 8 inches from the face of the shield. The effect in rear was very trifling indeed.

Another Whitworth flat-fronted shell was subsequently fired at this target, but in broke up in the gun.

Three rounds were next fired from the 10-in. gun with battering charges.

One 10-in. shot (Round 1727) struck very near one of the top corners of the port, and its point got in as far as the face of the back armour plate, but it did not indent it. The other shot (Round 1730) grazed the ground before reaching the target, and lost about 5 per cent , of its velocity by so doing. It struck on a backed portion of the shield. Its penentration could not be accurately ascertained, but it certainly did not reach the third armour plate.

The other round from the 10-in. gun was with a live shell (No. 1729) on the backed portion of the shield, and on a part from which the greater part of the iron concrete had been removed from between the front and second armour plates by previous rounds. The point of this shell passed about 1 in. beyond the back of the second armour plate. There was little or no effect upon the rear parts of the shield.

This completed the first day's firing. At this stage the committee expressed their opinion "that the shield had exhibited a very considerable amount of resistance and that it appeared in nearly every respect to be fully adapted to meet the requirements for which it was designed." They said also that it had been "subjected to a fire far more severe than it would probably have to endure under the conditions of actual warfare, both as regards shortness of range and number of hits; it nevertheless preserved its entirety, and the back or interior parts shewed no signs of penetration or sensible bulging." They spoke of the fastenings as having "proved eminently successful," but mentioned the weakness of the port frames, the employment of iron concrete between the armour plates, and the driving back of the shield to the injury of the temporary granite floor laid behind it, as points of exception to the generally satisfactory character of the shield. These matters will be noticed further on.

It should be observed that at this stage the original 5-in. intervals between the armour plates had increased to 8 in. between the front and second plates, and nearly 6-in. between the second and third.

In the nine effective rounds which had been fired up to this time, the shield had received blows equivalent in the aggregate to about 43,000 foot-tons.

Although the general efficiency of the shield had thus been established, it was afterwards thought desirable to subject it to further battering, principally for the sake of determining matters of detail for guidance in future constructions.

For this purpose two rounds were first fired from the 12 in. gun at an inclination of 60° to the shield, or 30° from the direction perpendicular to its face. This practice took place on the 1st July, 1870.

The gun was placed at 30 yards from the shield, but the charges were made equivalent to full battering charges at 200 yards.

The first of these two rounds (No. 1744) was with a 12-in. shot. It struck the shield about 2 feet from the left side of the port, at a place where the iron concrete had been completely driven out from behind the front armour plate. The penetration of the shot was slight, the point only indenting the second armour plate to a depth of about one inch, but the effect was rather severe in carrying away a triangular shaped piece of the front plate about 2 ft. 6 in. by 2 ft. 6 in., and driving it through the port. There was scarcely any sign of injury to the rear parts of the shield. The want of support to this part of the plate from the absence of the port frame and iron concrete, partly accounts for the exceptional effect of this round.

The next round (No. 1,745) was with a 12-inch shell, containing a bursting charge of 14 lbs. of powder. It struck on the right side of the shield, and burst on striking. The effect of the blow was to form an opening of about 24 inches by 16 inches in the front armour plate, and to buckle it. The plate was also cracked through for a length of about 12 inches up to its edge, but the shell only grooved the second armour plate to a depth of about half an inch.

The rear structure was not strained to any perceptible degree. The base plate of the shield was at this period $1\frac{3}{8}$ inch to the rear of its original position at its proper left end, and half an inch in front of its original position at its right end. The iron concrete was driven out freely from between the armour plates, as the port frames by this time had entirely ceased to act, and the large shot holes made by previous rounds facilitated its escape.

For further effects of these two rounds, see Table II.

The back structure forming the backing to the armour being still comparatively uninjured, it was determined that an effort should be made to overstrain some part of it, in order to ascertain the ultimate strength of its different parts. This was attempted by means of the 15-inch smooth bore Rodman gun, which happened to be still in front of the shield at a distance of 200 yards from it.

The practice took place on the 5th July, 1870, when six rounds were fired with charges of $83\frac{1}{4}$ lbs. L. G. R., which is equivalent to 100 lbs. of American powder. The effect of this practice has not been tabulated, but the general result may be said to have been as follows :—

The first round (No. 1,746) struck on a backed portion of the shield. This shot drove in a piece of the front plate to a depth of 12 inches, and lodged itself as it were between the front and second armour plates. The indent in the second plate was afterwards found to be 3 inches deep. The cracks in the front plate caused by previous rounds were extended. In rear a slight crack was observed in the case, and there was considerable movement of the entire shield, to the extent of about 2 inches backwards at one end of the shield, and $1\frac{1}{2}$ inch forward at the other.

The next round (No. 1,747) struck on the lower right corner of the port. The shot broke up, and the pieces passed through the port in large quantities. The second armour plate was only grazed, and cracked just at the edge of the port. In rear the casing was slightly bulged, and several tap screws were broken. There was not so much general movement of the shield as in round No. 1,746.

Round No. 1,748 struck high up on the shield. The shot passed through the front plate, and indented and cracked the second. By this round the whole of the right upper quarter of the front plate, which, by previous rounds, was nearly detached from the rest of the plate, was now quite separated from it, and hung only by an armour bolt. The end of the shield farthest from this shot moved forward about half an inch. A few rivets in the case were broken.

The next round (No. 1,749) was aimed so as to bring down the large detached portion of the front armour plate mentioned above, and this was effectually done by hitting the bolt by which the mass was suspended. This shot struck quite in the right top corner of the shield and partly on the masonry. It drove in the corner of the second armour plate to a depth of about 12 inches, and this plate was found to have been cracked more or less by some previous rounds. By this round the entire shield was moved back about two inches at the end struck, and forward one inch at the other end. There were two rivets sheared in the case in rear, and the arch stone which was struck was driven back about one inch.

The next two rounds were made to strike on the exposed face of the second armour plate with the object of more thoroughly straining the back structure. In the first of these (No. 1,750) the shot slightly grazed the granite pier, and half buried itself in the armour. The indent was $9\frac{1}{2}$ inches deep. The end of the shield struck was moved back about two inches at the top. The right side plate of the right pier of the casing was cracked from rivet holes in one or two places, and two or three rivets gave way by shearing.

In the last round (No. 1,751) the shot half buried itself in the armour, and bulged the face of the back armour plate about two inches deep and one foot across. The rear of the back armour plate was also bulged and cracked horizontally for a length of about 16 inches. The back plate of the case pier was at last cracked through at about 5 feet from the ground, and the previous cracks were a little opened out. The plate forming the left side of the case pier was bulged at about the level of the shot mark, and cracked for a length of two feet. An angle iron was also broken through and 15 rivets were sheared. The front plate of the right pier was also cracked. The crack formed by Round No. 1,724, on the back of the rear armour plate, was also extended about two inches lengthways. The shield was driven back in this round about two inches on the right.

As sufficient information had now been gained with regard to the general structure of the shield, and nothing more could be learnt in regard to detail, without an excessive expenditure of ammunition, the practice was discontinued.

The shield had now received 17 blows, with an average energy equivalent to about 5,321 foot tons per blow, giving an aggregate of upwards of 90,000 foot tons, or more than 1,000 foot tons per foot superficial of shield front, after deducting the space occupied by the port. This, it need scarcely be said, is far in excess of the battering that any previous shield has received at Shoeburyness.

With regard to the three points named by the Committee, as mentioned above, in which the shield was thought to be defective, the following observations may be made :—

First, as regards the port frames. As before explained, these both gave way in parts close to the angles, and this, notwithstanding that the principle of construction adopted had been experimentally tested under heavy blows from a falling weight without shewing that point of weakness. From their failure sufficient experience was gained to correct the defect, and in two subsequent trials (12th July and 30th August, 1870), with pieces of port frames introduced between armour plates, and strained by 600-pdr. shot (Rounds 1766 and 1767) planted close to them, ample strength has been secured.

As these trials were only to decide points of detail, they will not be further noticed in this paper.

Before leaving this part of the subject it may be observed that whatever material may be used as filling between the armour plates, there will be the same necessity for strong port frames. This opinion is strengthened by the result of a trial made 16th September, 1870, with a target composed of two armour plates with 6 in. of oak between them. The oak was put together with iron dowels. A 600-pdr. shot was fired at it (Round 853), when the oak was driven out with great force, breaking in doing so a strong bridge rail, 3½ in. deep; several dowels were broken. The splinters of wood would have been very destructive.

Next, as to the use of iron concrete being in the opinion of the committee objectionable as filling between the armour plates. In the first place, too little regard seems to have been paid to the advantage gained by the great weight of this material. As used in this shield the concrete was about half the weight of an equal bulk of cast iron, and, of course, this great weight contributed in an important degree to the general stability of the shield. This concrete is also of a consistency which is favourable to the even bedding of the armour plates over their whole back surface when struck by shot. This was particularly noticeable, in the present trial, in the absence of cracks in the armour plates after the first few rounds.

But on the other hand it is a costly and troublesome material to use, and there would be some difficulty in getting, at reasonable rates, sufficient cast iron borings to work with it upon a large scale.

If it should squeeze out under shot-blows near the port, no doubt it may be very dangerous to the gun detachment, but it is not admitted that this need occur. By the proper use of other material, such as wood or rope, in the parts immediately around the port frame, there is every reason to believe that the escape of the iron concrete could be prevented, even if the intervals between the armour plates should increase as much as they did in this trial. But the increase from 5 in. to 8 in. that took place in the interval behind the front armour plate in this instance, after blows equivalent to some 40,000 or 50,000 foot-tons, may be regarded as altogether exceptional and excessive, and in practice not half that increase would ever occur.

The Committee also noticed the softening of the iron concrete when heated by the entrance of a shot or shell, and its tendency in that condition to escape through the shot holes made in previous rounds; but on this it may be observed, that in practice a shield will scarcely receive several rounds from such guns as those at Shoeburyness planted close together, and even if the concrete does run out in parts, the resistance of the shield is not impaired to a very serious extent, as will be shewn by an experiment noticed later in this Paper. Besides, the concrete soon sets again as hard as ever.

However, considering all things, it may be wise to abandon this particular concrete for the filling between the armour plates, and even to give it up for the casing also, if there should be difficulty in procuring borings on a large scale at low rates.

As regards a substitute for the iron concrete, either brickwork in asphalte, or Portland cement concrete, will, judging from the experiment of 15th January, 1869, p. 265, Vol. XVIII, answer very well, and probably it will be well to use wood immediately about the port frames.

The only other point to notice is that of the shifting of the shield in the course of this trial. At the conclusion of the experiment the base of the shield was found to have been driven back some 7 or 8 inches, and to allow of this, the holding down bolts had been bent to a considerable curve, and had also been elongated.

On this it should be explained, that the granite blocks behind this shield were much lighter than those used in actual works, and were laid in a much more temporary manner than usual. In fact, in many respects they did not represent the floor of our casemated batteries at all. But still the derangement of the racers would be so serious a matter in action that it well deserves attention. In the first place, the ends of the base plates under the piers should be very firmly secured, and the holding down bolts should have large cross sectional area to resist the backward movements. It would be well perhaps to introduce some wood between the back edge of the base plate and the granite floor, and even in some instances to introduce under the base plate heavy iron cramps, let into the masonry and dovetailed in it, with stops to check the movement of the shield in the rear. These cramps should be so placed and arranged as to relieve as far as possible the stones in which the racers are laid. With these precautions there will be no danger of the racers being displaced under a very considerable amount of battering.

TABLE I.

Experimental Shield, 1869.

Report of Practice on the 2nd of March, 1870,—Range, 200 yards.

Photographic No. of Round.	Gun.	Charge and brand of Powder. lbs.	PROJECTILE. Nature, Length, Weight, and Diameter.	Striking Velocity. feet.	$\frac{Wv^2}{2g}$ in foot tons on impact.	Foot tons per inch of shot's circumference	Observed Effects.
1721	12-inch M. L. R., No. 9.	76 pellet of 1867. 23·5 by 11·25 inches.	Palliser cored shot, 26·2 ins., 602 lbs. 8 ozs., 11·92 ins.	1190	5916	158·0	Struck 30 in. from left edge, and 43 in. from base. Direction of shot inclined to the right at an angle of 12 deg. from the vertical. Diameter of hole, 15 in. by 13 in. Penetration, 23 in. Radial deviation from point aimed at, 28 in. high and 11 in. right. *In rear.*—Inner plate opened at weld at 1 inch from front of plate, opening extending for a length of 17·5 in., very slight bulge over inner surface of plate. Iron port frame at left side of port between 2nd and 3rd plate forced out, the greatest amount being 1·7 in. at a height of 1 ft. from the bottom of port hole; wood packing squeezed out between each layer of plates. Stone blocks of arch above shield opened at two of the joints. Cement between shield and granite at left side broken away for a length of 5 ft. 6 in. Granite at level of floor splintered.
1722	,,	,,	Palliser shell, 29·2 ins., 598 lbs. 8 ozs., 11·92 ins. Bursting charge, 14 lbs.	1170	5681	151·7	Struck 36 in. from right edge, 29 in. from base. Diameter of hole 13 in. by 13½ in. Burst. An opening 1·8 in. wide between inside port frame and second 5 in. plate. Front plate driven back 1¼ in. at top and 1 in. forward at base. Penetration, 23·2 in. Right edge of shell hole on bolt which was driven in 4 in. and broken. Radial deviation, 12 in. high and 2 in. left. *In rear.*—Inner plate bulged 0·25 in. at level of top of case. Port frame between inner and centre plate forced out 1·5 in. at 11 in. from bottom of port-hole, the displacement ending at 6 in. from the top. Wood packing and iron concrete forced out, and portion of latter driven inside port. Back of lower casing bulged out 0·5 in. at top, and buckle 0·35 in. vertical girder. Concrete cement filling in between granite and shield at right side knocked out the whole length. Opening at one of joints of arch.
1723	,,	,,	Palliser cored shot. As before. 601 lbs. 8 ozs.	1132	5345	142·7	Grazed 41 yards short, and struck at junction of shield and masonry just over left side of port-hole. *This round was aimed at a point* 18 *in. from base.* *In rear.*—Angle iron on right side of left pier (joining top of case to bottom), opened out 0·25 in. at outer top end, and cracked in bend at top through two rivet

Photographic No. of Round.	Gun.	Charge and brand of Powder. lbs.	PROJECTILE. Nature, Length, Weight, and Diameter.	Striking Velocity. feet.	$\frac{Wv^2}{2g}$ in foot tons on impact.	Foot tons per inch of shot's circumference	Observed Effects.
1723 contd.							holes; also cracked from inside edge to the 2nd and 3rd rivets from the bottom. Slight opening at joint of stone blocks of arch.
1724	12-inch M. L. R., No. 9.	76 pellet of 1867. 23·5 by 11·25 inches.	Palliser shell. As before, 605 lbs. Bursting charge, 14 lbs.	1177	5812	155·2	Struck 33 in. from right edge, and 60 in. from base. Diameter of hole, 13 in. by 12 in. Front plate driven back 3 in. Centre 5 in. plate driven back 2 in. at top. Penetration, 23·2 in. Radial deviation, nil. *In rear.*—Inner plate cracked across at 2 ft. 4 in. from top of case, and bulged out 1·5 in.; opened in welds at 1 in. and 1·8 in. from front surface, extending for a length of 6·5 in. and 4·7 in. respectively; and cracked through from the back for a thickness of 3·2 in. Iron port frame forced out 9·3 in. at 10 in. from bottom of port and sloping up to nil at top. A good deal of iron concrete forced out and driven inside as langridge in a molten state. Iron casing of right pier slightly opened.
1725	Whitworth 9-inch M. L. R., experimentl No. 361.	50 (tubular cartridge) R. L. G., 24, 12, 67., lot 1296, 29·25 by 7·9 inches.	Whitworth steel flat-fronted shell. 31·5 inches, 403 lbs., 8·94 ins. major, 8·118 ,, minor, Capacity, 12 lbs. Filled with sand and sawdust.	1166	3799	136·7	Struck on port sill 25 in. from base, and 13 in. from left of port. Centre of shot hole 5½ in. below port sill. Broke away a piece of front plate measuring 13 in. by 11 in. Indented centre 5 in. plate, and forced it back 4½ in. Shell broke up in numerous fragments. Radial deviation, 10 in. high. *In rear.*—One rivet head in rear angle iron at the top of bottom casing broken off. Upper casing a good deal cut by splinters of shell and plate, and centre granite block of arch cracked for a length of 21 in. at 6 in. from rear face, where struck by a splinter. Pieces of plate (7), and shell (14, and base plug), and concrete driven inside port—some lying on top of casing; horizontal timber frame-work 11 ft. in rear of shield a good deal marked with splinters, the damage extending 16 ft. laterally and to a height of about 10 ft.
1726	,,	,,	Whitworth steel ogival-headed shell. 33·7 inches, 392 lbs. 8 ozs., 8·94 ins. major, 8·118 ,, minor. Capacity, 12 lbs. Filled with sand and sawdust.	1183	3925	141·2	Struck 21 in. from left edge, and 21 in. from top. Shell remaining in hole, base projecting 8 in. Shell not broken. Penetration, 25·7 in. The total thickness between rear and front plates now 29 in.—the increase of 4 in. due to bulge and forcing back of plates. Radial deviation, 7 in high and 7 in. right. *In rear.*—Two rivets broken in rear angle iron at the top of bottom casing. Wood filling in piece and iron port frame at left side of port further forced out 2·3 in., thus projecting 4 in.

Photographic No. of Round.	Gun.	Charge and brand of Powder. lbs.	PROJECTILE. Nature, Length, Weight, and Diameter.	Striking Velocity. feet.	$\frac{Wv^2}{2g}$ in foot tons on impact.	Foot tons per inch of shot's circumference	Observed Effects.
1727	10-inch M. L. R., experimentl No. 323.	60 R. L. G., lot 1296, 24, 12, 67., 27 by 9 ins.	Palliser cored shot. 24·5 ins., 402 lbs. 8 ozs., 9·92 inches.	1230	4223	135·5	Struck 54 in. from left edge and 81½ in. from bottom. Front and centre 5 in. plates cracked through between periphery of shot hole and port side. Port frame bent back and cracked through. Penetration with bulge 25 in. Radial deviation, 18·5 in. high and 11 in. left. *In rear.*—Centre plate at left hand side of port, at top, forced back 3·3 in., leaving only 1·6 in. between its inner surface and the outer surface of the 3rd plate. Centre plate completely broken through and opened at welds in two places; crack 1·5 in. long on inside of 3rd plate at top bend of port-hole. Wood filling at side of port more forced out, and iron concrete driven out. Casing plate in line of impact bulged back 2 in.; one rivet broken in rear angle iron at the top of bottom casing. Crack and opening in angle iron on right side of left pier, made by No. 1723, increased.
1728	Whitworth 9-inch.	50 as before.	Whitworth steel flat-fronted shell. As before. 389 lbs.	—	—	—	Shell broke up in gun.
1729	10-inch.	60 as before.	Palliser shell, 401 lbs. 8 ozs., 9·92 inches. Bursting charge, 9 lbs.	1264	4448	142·7	Struck 16½ in. from right edge, and 26 in. from top. Diameter 11 in. by 11 in. The hole made by this round ran into 1724. Port frame projecting inwards 2¾ in. at top, and 3½ in. at bottom. Whole shield driven back 1½ in. on right at top, and forward ½ in. on left side. Penetration 20·2 in. *In rear.*—Shield shifted back on right side 1·5 in., and forward on left side 0·5 in.
1730	"	"	Palliser cored shot. As before. 399 lbs.	1174	3813	122·4	This shot was aimed at a point on left flank, 18 in. from base of plate. It grazed 33 yards short, and struck 19 in. from bottom, and 43 in. from left edge. The port frame between the front and centre 5 in. plates was forced diagonally right across the port-hole, practically closing it up. *In rear.*—Piece of iron port frame 19 in. by 12 in., driven 4 ft. inside shield through port-hole, and another piece 11 in. by 5¾ in. on top of casing, with fragments of iron concrete. Shield very nearly set back into its position previous to preceding round. The granite blocks in rear of shield on level of floor were forced up between 3 in. and 4 in., and split at a depth of 2½ in. along the whole length by the shifting of the shield during the practice.

Palliser projectiles.—Heads 1·5, chilled, and bodies cast in sand.

TABLE II.

EXPERIMENTAL SHIELD, 1869.

Report of Practice on the 1st of July, 1870.—Range, 30 yards.

Photographic No. of Round.	Gun.	Charge and brand of Powder. lbs.	PROJECTILE. Nature, Length, Weight, and Diameter.	Striking Velocity. feet.	$\frac{Wv^2}{2g}$ in foot tons on impact.	Foot tons per inch of shot's circumference	Observed Effects.
1744	12-inch M. L. R., No. 9.	$73\frac{1}{3}$ pellet.	Palliser cored shot, 26·2 inches, 602 lbs. 11·92 inches., 1·5 head. Fired at angle of 60 degrees with face of shield.	1190	5900	158	Struck 2 ft. from the left side of port, and 5 ft. 6 in. from floor. A triangular piece of front plate, about 2 ft. 6 in. by 2 ft. 6 in., broken off and driven in four principal pieces through the port. Indent in second armour plate 1 in. deep, by $2\frac{3}{4}$ in. wide. Front plate cracked up to No. 1726 and to 1721. Head of bolt near right upper corner of port broken off. The shot broken up on the second plate. *In rear.*—The pieces of the front plate struck the supports and timbers. Some tap screws a little started.
1745	"	"	Palliser shell, 29·2 inches, 599 lbs., 11·92 inches. Bursting charge, 14 lbs. 1·5 head. Fired at angle of 60 degrees with face of shield.	1170	5700	151·7	Struck 2 ft. from the right of shield, and 3 ft. 3 in. from bottom. Shell burst on striking. Piece of front armour plate about 17 in. by 14 in. driven in. Cracks to No. 1722 and 1724, and between them, and to edge of plate. Head and pieces of shell marked face of second armour plate about $\frac{1}{2}$ in. deep, and remained between the front and second plates. *In rear.*—Little effect. Top of case overhung at rear $3\frac{1}{2}$ in. on left, and $2\frac{1}{2}$ in. on right. The masonry pier cracked.

Palliser projectiles.—Heads 1·5, chilled, and bodies cast in sand.

TARGET COMPOSED OF THREE 5-IN. PLATES WITH VACANT SPACES BETWEEN.

In the course of the foregoing description of the practice at the casemate shield, allusion is made to the fact of the partial escape of the iron concrete from between the armour plates not impairing the efficiency of the shield to a very serious extent.

To ascertain the truth of this, a small target was prepared at Shoeburyness, consisting of three 5-in. plates blocked out from each other at distances of 6 in. The plates had all been more or less injured in former trials, for which some allowance has to be made, and they were set up (not bolted together) in a very temporary way, but still an interesting and reliable result was obtained with them.

The gun used was the 12-in. M.L.R., and it fired a Palliser shot with a 1·5 diameter head, the charge being regulated to represent a full battering charge at

MEN

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AT SHOEBURYNESS.

200 yards. Thus this round (No. 824) compares with round 550, and in all, except as to head of shot, with 1664, and 1679, at pages 270 to 273, Vol. XVIII.

The trial was on the 20th May, 1870.

The shot went clean through the front plate, making a hole 13 in. by 12 in., and turned slightly to its left. The back of this plate was broken away over 19 in. by 21 in., and buckled about 3 in. more than before.

It next drove through the middle plate, raising up in rear a large cone which flattened its top (20 in. in diameter) against the face of the rear armour plate. The middle plate was now buckled about $4\frac{1}{2}$ in. and much broken, but it had been previously buckled about $3\frac{1}{4}$ in.

On the face of the rear plate some of the shot was found sticking, as if splashed against it, in a finely divided state When this splash was afterwards removed, the indent in the face of the plate was found to be only about $\frac{1}{2}$ in. deep, but there was a very large star crack on its rear face, and the buckle caused by previous practice was much increased.

The most important feature of this trial is the entire disintegration of the shot. This result is very extraordinary, but it was not unexpected, as a similar result had been observed on two former occasions, when shot struck similar structures. It was clear, on examination of the pieces of the shot, that this peculiar effect was not due to any defect in the metal. It was a good specimen of a Palliser shot, and on any other target that has yet been tried, whether solid or compound, its head would have kept together in one large piece, and its point would have been unaltered in form. In this instance so complete was the demolition of the shot, that 400 lbs. of it were found chiefly in small pieces between the front and second plate, and $25\frac{1}{2}$ lbs., chiefly in fine pieces, between the second and rear plate, the rest being dispersed about the practice ground.

As before stated, much of the observed effect on the plates is to be attributed to the injuries they had received in former trials, so that it may fairly be inferred that the penetration of a chilled shot into a plate upon plate target with vacant intervals, will not be greater than when the intervals are filled with concrete, or other comparatively hard substance; but it does not follow that a target with air spaces would resist a battering so well as the other, for there is strong reason to believe that, without some filling between them, the armour plates would crack much more, and give way under repeated blows by that means, without developing a fair amount of general resistance in the structure.

Resistance of Ships' Decks.

The last trial that will be mentioned is one not strictly belonging to the subject of this Paper, but yet not altogether out of place in it.

The target measured 20 feet by 10 feet, and was formed of six iron deck beams, 10 inches deep, and 2 feet apart, covered over one half with 1 in. iron plating, made up of two $\frac{1}{2}$ in. plates, with 5 inches of deal in planks, 8 in. wide, on the top of it; and over the other half with two thicknesses of $\frac{3}{4}$ in. plates, and $4\frac{1}{2}$ in. of deal planks. The wood was held on by $\frac{7}{8}$ in. bolts tapped into the plating.

The target was set vertically, and the 13 in. sea service mortar was laid at it, from a distance of 20 yards, at such an angle that the shell struck the target at an angle of 60°.

The first practice took place on the 7th April, 1870. The shell were common shell, filled with sand and weighing 207 lbs.

The first round (No. 1,731) was fired with 7 lbs. L. G. to give the terminal velocity of a shell fired with a 20 lbs. charge at 45° elevation. The striking velocity was 514 feet per second, and the energy on impact was 379 foot tons, or 9·4 foot tons per inch of circumference of shell. It struck the 1 in. plate portion of the target, and went clean through, making a hole which measured in front about 16½ in. by 18 in. to 12 in., and in rear 24 in. by 18 in. The shell broke up into large fragments, some of which were carried 80 yards beyond the target. One deck beam was broken away for a length of 14 in. The fastenings in the vicinity of the hole were uninjured.

The next round (No. 1,732) was fired with the same charge at the 1½ in. plate portion. It went completely through between two deck beams, making a hole 18. in. by 13 in. in front, and 16 in, by 16 in. in rear. One deck beam was slightly bulged.

In the third round (No. 1,733) the shell was fired with a reduced charge of 3½ lbs. of powder, and struck with a velocity of 327 feet per second, giving an energy equivalent to 154 foot tons or 3·8 foot tons per inch of its circumference. It hit the 1½ in. plate portion and rebounded 10 feet, unbroken. The deck plating was bulged 3·3 in. over a surface of 17 in. by 17 in., and a joint of the rear ¾ in. plate was opened across the bulge to the extent of 1 in. The front plate was also cracked and daylight was seen through it. One deck beam was broken through its web and bulb flange, and bulged 1·7 in. at the centre of a length of 6 feet.

The next round (No. 1734) was the same as the last. The shell struck on the 1-in. plate portion, and went through. The hole in front measured 16½ in. by 22 in. to 14 in., and in rear 20 in. by 12 in., the deck plating being broken over a surface 2½ ft. by 2 ft. The web and bulb flange of a deck beam were broken away over a length of 2 ft. 7 in. The shell was found uninjured behind the target.

Subsequently, to test the effect of direct fire from guns on ships' decks, two rounds were fired with blind chilled Palliser shell at this target from the 9-in. muzzle-loading rifle gun of 12 tons, the deck being inclined at an angle of 8°. These two rounds were fired so that the shell crossed the deck planks, and were therefore in the direction of the beam of the ship. The gun was placed close to the target.

The first of these (No. 1742) was fired with a 31½-lb. charge to represent a full battering charge at 800 yards range. This made a long scoop through ten of the deck planks, just touching the deck plating along the top of a deck beam. Through 2 ft. 4 in. of its passage it was on the 1½-in. plate portion. The skin was cracked a little. The shell passed out to sea entire.

The other round (No. 1743) was fired with a full battering charge (43 lbs). This shell made a long scoop through the planks, much as in the last round, and ran along the deck plating between two deck beams. The plating was bulged severely, and one deck beam was bent down.

This shell also passed out to sea uninjured.

T. I.

PAPER XIII.

NOTES ON THE OPERATIONS ROUND SHANGHAI IN 1862 - 63 - 64.

By Lieut. Colonel C. G. GORDON, C.B., R.E.

The following notes deal only with the military operations of the foreign-officered and the co-operating Chinese forces against the Taiping rebels in the province of Kiangsoo, in the years 1863-64. For the history of this rebellion, and the reasons why our Government desired its suppression, other works must be consulted.

The country in which the operations were carried on consists of the triangular alluvial tract between the Yangtze Kiang and Hangchow Bay; it is perfectly flat and intersected in every direction by large deep creeks and canals, varying from 10 to 100 yards in width; these sometimes widen out into large lakes, 8 to 10 and even 40 miles in length and breadth, narrow roads or causeways generally following the courses of the principal canals to which they serve as towing paths, and over which they cross at times by stone and wooden bridges of various sizes. The country is covered in prosperous times with large and flourishing villages and towns, the principal ones being surrounded by brick walls from 18 ft. to 24 ft. high, generally possessing four gateways which project as bastions to the general line of the walls: outside these gates are large suburbs, where most of the trade is carried on to avoid the duty on goods taken through the gates.

The walled towns are placed on the principal canals, generally where two or more meet, and it is the depth and width of the canals which decide the size of the villages or towns, while the importance of their junction decides their being walled or not.

Thus though there seems only an intricate network of creeks, a careful observer will as soon perceive the main features of the country as if there were ranges of mountains and corresponding valleys; he will see by the size of the arches on some of the canals that the largest boats can pass, and will comprehend that these must lead to important places.

In the spring of 1862, the rebel leaders held the whole of the towns, with one exception (Sungkiong), within ten miles of Shanghai; they had contemned the dispatches of the British and French authorities, directing them to keep a radius of thirty miles free from their troops, and had hinted their intention of taking Shanghai itself. The British and French Admirals and Generals determined on driving them back to the thirty-mile radius, for which purpose it was necessary to capture the towns of Kahding, Singpoo, Najow, and Cholin.

Kahding was breached and stormed on the 1st May, 1862; Singpoo, on the 13th; Najow, on the 17th; and Cholin, on the 20th, by the British and French forces; the garrisons of these towns were allowed to escape through the cities not having been surrounded. A detachment of British troops was left with the Imperialists to garrison Kahding; and on the day of the capture of Cholin, information was received that Chung Wang, the chief leader of the rebels, had advanced on and surrounded that place, after defeating and capturing an Imperialist force, which had imprudently advanced from Kahding towards Taitsan. The morning of the 21st May, 1862, saw the allied British and French forces returning from Cholin after burning it and blowing up one of its gates, at the same time that the rebel garrisons of three cities—Yongmei, Naiwai, and Chuenza, numbering from 6,000 to 8,000, and of Cholin and Najow, who had escaped—were defiling along the sea-wall on the edge of Hangchow Bay, the capture of Cholin having completely cut them off from their comrades. Leaving a detachment at Najow, the allied forces returned to Shanghai, and advanced again to Kahding. The rebels fell back on their approach. The garrison being withdrawn, the allied forces returned to Shanghai, and the rebels re-occupied Kahding, and flocked down to and surrounded Singpoo, which was then occupied by the foreign-officered force of Chinese, under an American, named Ward, whose head-quarters were at Sungkiong. On the 10th June, 1862, the allied forces were obliged to advance to Singpoo to relieve its garrison: the rebels fell back on their approach, and re-occupied it on its evacuation. Thus ended the spring operations, leaving the rebels in possession of Kahding and Singpoo.

On the 1st October, 1862, the British and French forces again advanced on Kahding, breached the wall and retook it, the garrison escaping. Singpoo was taken by Ward's foreign-officered force of Chinese, on the 17th August, 1862. The end of 1862, found the thirty-miles radius cleared of the rebels, and the cessation of active operations against them on the part of the British and French forces in the province of Kiangsoo.

It is necessary to describe the foreign-officered force known by the Imperial Government under the name of "Ever Victorious Army," or Chắng Sheng Chíun. Its creation is due to the American Ward, who, on the invasion of Kiangsoo by the rebels in 1860, undertook the recapture of Sungkiong with a party of 100 foreigners for a certain sum of money. This he accomplished by seizing a gate at dusk, and maintaining his party there against the repeated attacks of the rebels till the morning, when the Imperialists came up to their assistance. The impetus that this success gave to the desertion of seamen from the Royal Navy and merchant shipping to join him, led to Ward's being arrested and his foreigners disbanded. He then took to drilling Chinese, the funds for their support being found by the rich merchants of Shanghai, and support was also given him by the British authorities in the way of allowing him to purchase old arms. He eventually worked this nucleus into a force of from 6,000 to 7,000 Chinese, officered by foreigners of all nationalities, and of all degrees of life. They were armed with Tower muskets, and had a powerful artillery. It was with this force he breached, assaulted, and captured Singpoo in August, 1862. He was killed in the attack of Tseki, September 21st, 1862, and left the command of the force to Burgevine, also an American. Ward was a brave, clear-headed man, much liked by the Chinese mandarins, to whom he was courteous in his manner, and a very fit man for the command of the force he had raised.

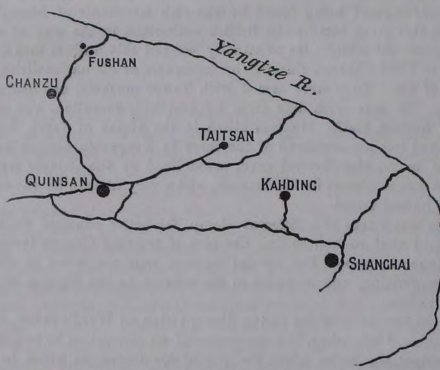
Burgevine was a man of a different stamp, far better educated than Ward; and it is said that to him is due the idea of training Chinese troops in the foreign manner to oppose the rebels; he was, however, when in command, indolent, temporizing, and arrogant in his manner to the Chinese merchants who paid the force.

He took the command of the Chắng Sheng Chíun on Ward's death, and held it till December, 1862, when, in consequence of an altercation he had with one of the principal Mandarins about the pay of his troops, in which he lost his temper and struck the official, he was removed by Li Hung Chang, the Governor of Kiangsoo, from the command of the force. The only action which occurred during his tenure of office was on November 13th, 1862, when he repulsed with great slaughter, near Powokong, a large force of the rebels who had moved down to attack Singpoo.

Previous to Burgevine's removal from the command of the force, Admiral Sir J. Hope had lent him as chief of his staff Captain Holland, R.M., and on the fracas above alluded to having taken place, the Governor Li applied to General Staveley to appoint an officer. General Staveley nominated the writer of these notes; but unwilling to supersede Capt. Holland, he suspended his assumption of the command until the British Minister at Peking had given his decision on the advisability of a British Officer taking any part in the matter. Captain now Major Holland retained the command till March 23rd, 1863, when the Home Government instructed the General to place a British Officer in charge of the force if opportunity offered itself. The General consequently named the undersigned, who took over the command at the end of that month.

During Major Holland's tenure of office, he had made an expedition against Taitsan, a city north of Kahding, breached the walls, 14th February, 1863, near one of the gates, but failed in the assault and lost two 32-pounders, which the rebels, by a rush out over the breach, captured.

At this epoch the Imperialists were in a difficulty about the city of Chanzu, whose rebel leader had with his troops given in their adhesion to the Imperialist Government; this city was now hemmed in by the rebels under Chung Wang who had captured the fortified post of Fushan which barred the passage from the Yangtze to Chanzu. Chanzu stands some 25 miles and Fushan about 5 miles from the Yangtze,



Previous to the writer's taking the command, several attacks had been made on Fushan, which the rebels had repulsed, and the state of Chanzu was most critical. The Governor Li requested that Fushan might be taken, and on the 31st March, 1863, the 5th Regiment, four 12-pounder howitzers and a 32-pounder on siege carriages, were embarked from Sungkiong and proceeded up the Yangtze to the Imperial camps which were posted near Fushan. The troops were disembarked on the 2nd, and the place reconnoitred on the 3rd.

The rebels held the large stone bridge over the canal which runs from Chanzu to the Yangtze; they had enclosed a considerable number of houses with a strong loop-holed wall, ditches and abattis on each side of the bridge, which was on a bend of the canal; but near it on the west side of the canal were some ruins which afforded cover close up to the stockaded positions, and it was in these ruins the guns were placed in the night of the 3rd of April. It was determined to attack the eastern stockade, though the troops and guns were on the western side of the canal, it having been observed that the canal leading to Chanzu was but imperfectly staked, and that boats to form a bridge could be passed up it to the walls of this stockade, which stood somewhat in advance of the western one; the rebels had relied on the width of this canal and had no abattis along the walls; the guns also could bear both on the connecting bridge and on the main road leading from Chanzu, and thus prevent reinforcements coming up.

Could confidence have been placed in the troops the whole position could have been turned, and the result would, in all probability, have been an evacuation; but the troops had been twice defeated and their *slight* morale was shaken under the continual changes of commanders.

At 7 a.m. the guns opened on the stockades at a distance of 700 yards, the walls fell in flakes under the 32-pounder shot, a breach was soon made and the rebel fire silenced. At 10 a.m. the boats advanced slowly along the canal and pulled up the stakes, and the 12-pdr. howitzers were advanced to the edge of the ruins; a portion of the storming party were in the boats which, under the foreign officers, formed a bridge and the place was entered, the rebels leaving the other stockade as the men landed; the loss was two killed and six wounded. The rebels made a vigorous and nearly successful attempt to retake the position about an hour after its capture, which was repulsed with difficulty; they had sent reinforcements into the works during the firing; which, considering it was along the road directly in the line of fire of the 32-pdrs, speaks well for their courage.

On the night of the 4th April, Chung Wang and his troops fell back from Chanzu, which, nearly at its last extremity, opened its gates to the Imperialists. Chung Wang had made many attempts to take the place and had tried to breach the walls with the two 32-pdrs. he had captured at Taitsan, one of which had burst from the rough shot fired from it.

The expeditionary troops returned to Sungkiong on the 6th April, and to the end of the month every effort was made to get the troops, which numbered from 3,000 to 4,000, properly equipped, and to organize the departments.

The force was divided into five regiments of infantry and one of artillery, averaging from 600 men each, officered by men of all nationalities, the non-commissioned officers being Chinese; to each regiment was attached an interpreter. The artillery consisted of two 8-in. howitzers, four 32-pdr. 25 cwt. guns, three 24-pdr. howitzers, twelve 12-pdr. howitzers on naval field carriages, eighteen 12-pdr. mountain howitzers, fourteen mortars, of which four were 8-in. and the remainder $5\frac{1}{2}$-in. and $4\frac{2}{5}$-in., and three rocket tubes. The guns were on siege carriages, and the whole of the ordnance and ammunition were contained in sixteen large boats. A large assortment of planks for platforms and bridges, rope and 3-in. elm mantlets, 10 ft. broad and 8 ft. high, which were placed by the guns in action, and which answered admirably in protecting the gunners, were carried with these boats, together with about 150 feet of Blanshard's infantry pontoon bridge. The flotilla consisted of from 40 to 50 Chinese gunboats, which would carry from 40 to 50 men each, thus enabling 2,000 infantry to be moved by water with celerity in any direction; these boats carried a 9-pdr. or 12-pdr. gun in their bows. The rations were conveyed in eight or ten large boats, and consisted of rice and pork sufficient for the whole force for ten or twelve days.

The commanding officers of regiments had a proportion of bamboo ladders (with planks strapped on them) and tools handed over to them, so that each regiment could march across any country, however intersected with creeks; they also had a party of coolies to carry the spare ammunition. The men were armed generally with Tower muskets, with some 500 to 700 Enfields among the force.

The commanding officers dealt with their prisoners according to a regular code, only extreme cases being brought before the Commanding Officer of the force, whose endeavour was to leave as much as possible to the commanding officers of regiments, after generally defining what he considered the interior economy of the troops should be; acting in the same manner with respect to the Commissariat and Military Store Departments, and dismissing the men who failed to carry on their duties. By this means, he eventually got leaders who were zealous and pains-taking, and who could be trusted. By frequent personal and minute inspection, without the slightest attempt at formality in the same, he had the personal assurance of the state of each regiment and department.

The hospital arrangements were under the care of Staff Assistant Surgeon Moffitt, who knew his work so well as never to require anything more than encouragement, and whose name and skill will be remembered for many a long day in the province of Kiangsoo.

It is not necessary to dwell longer on the organization of the force. The arrangements were just such as any officer invested with absolute power and a little common sense would carry out. As a general rule orders were given *viva voce*, and were seen carried out; forms and ceremonies were as much as possible avoided (an advantage, as there were many Americans in the force), and each commanding officer, supreme in his command, felt himself trusted.

Attached to the force at various times were from one to three small paddle-steamers 90 ft. long and 24 ft. wide, drawing 3 ft. to 4 ft. of water, carrying a 32-pdr. gun in the bow, and a 12-pdr. howitzer in the stern. These were commanded by Americans, and did first-rate service.

The force at the end of April was thus well equipped in every way, its departments organized, and the means of transport available to move it in any direction with celerity, and it was now determined to use it against the rebels. The Governor Li had stated that the rebel chief Isah, of Taitsan, was prepared to give over his city if the adjoining town of Quinsan was attacked; and accordingly the force started for that town on the 27th April. It reached Lokapan, a village fifteen miles from Quinsan, on the 30th April, 1863, when dispatches arrived from Li to the effect that Isah had treacherously decoyed his brother's troops into the city of Taitsan, that 1,600 of them had been killed, and his brother's camp taken. He requested that the operations against Quinsan might be deferred, and that the force should march across and attack Taitsan. On the 31st they marched to the south gate of Taitsan, and on the 1st May, turned towards the west gate, where the rebels had two large stockaded works some 700 yards from the walls of the city. Fire was opened at 1 p.m. on the nearest stockade, and in the meantime a regiment, under the cover of the ruins which lay between the stockade and the town, pushed on in skirmishing order to cut off the retreat of the defenders of the stockade, on whom the artillery fire had begun to tell. Just as it was decided on attempting the assault of the work, its defenders, seeing their retreat menaced, evacuated it, and a few shots compelled the rebels to retreat from the other stockade. Thus fell with little loss the two and only outworks of Taitsan.

On the morning of the 2nd May, a regiment was detached to prevent the escape of the rebels from the north gate, and thus the east gate only was open to them, and that led away from their supporting cities and would force them to make a long detour by byeways to escape. Had there been troops available this exit would also have been closed.

On reconnoitring the town, it seemed that the creek leading up to the west gate, and then bifurcating, formed the ditch ; it was clear of stakes, the rebels having depended on the exterior stockades, now captured, to prevent an attack on that side. As this would enable boats to be pushed up into the ditch to form a bridge, it was determined to attack here, though disadvantageous on account of the projecting bastioned gateway.

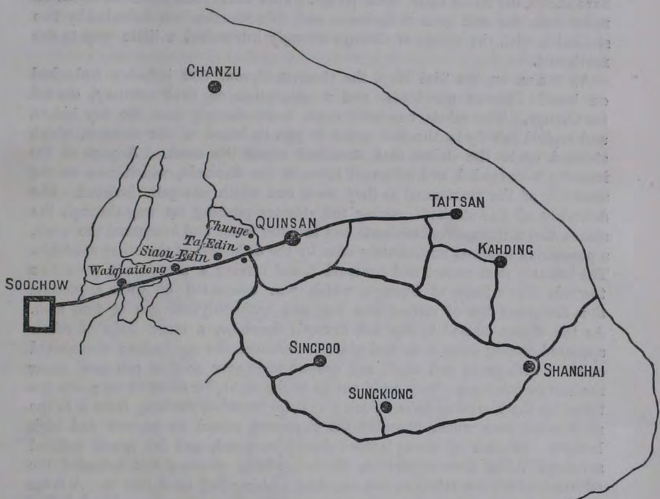
The guns were landed one by one among the ruins of the suburb, and opening at 500 to 600 yards distance from the wall, soon began to bring it down. As the enemy's defences got more and more dilapidated, the guns were moved nearer, a heavy fire of musketry was kept up on the walls, and under this fire the boats were pushed up little by little to the breach. The rebels kept up a very fair fire, but lay concealed. At 3 p.m., the breach was practicable, and the boats being pushed up to the ditch, the storming party advanced. In a moment the breach was crowded with rebels, who stood boldly up, and threw bags of powder, with fuzes attached, into the boats. The troops pushed on across the bridge—one of the boats of which had been sunk by the explosion of a powder bag—but could not mount the breach, the rebels presenting a forest of spears against their advance. Two 8-in. howitzers were then brought up, and firing blind shells over the heads of the stormers, mowed down the defenders of the breach in scores, though they still attempted to fire down at the storming party which lay in the ditch. The sounding of the "advance" made them show again, but after a time they got more wary, and another attempt was made to mount the breach, again to be frustrated. The rebel chief's snake flags still floated out on the breach, and till he left, it was said the breach would be defended. A violent fire was directed on the spot, which hurled masses of brickwork on the crouching rebels. Another and third attempt by a fresh regiment was made to mount, which was stoutly met by the rebels, and the contending bodies swayed on the edge of the breach for a moment, and then the stormers surged over and the place was won, the flags of the chief disappearing at the last moment. On the breach the rebels lay in great numbers; among them, fighting to the last, were two Americans, two Frenchmen, and three Sepoys of the 5th Bombay Native Infantry—deserters. Several other foreigners who were fighting for the rebels escaped; and in the town was captured Private Hargreaves, a deserter from the 31st Regiment, severely wounded. The losses the force had sustained incapacitated it from an active pursuit, and the chief, Isah, with the greatest part of his fighting men, who numbered from 8,000 to 10,000, escaped to Soochow. Had the Imperialists been active they might have caused much greater loss in the pursuit, but they were cowed by the disastrous treachery of the previous week, and did little beyond looking on.

Two mandarins of high rank and 300 Imperialist soldiers, who had been taken prisoners by the previous treachery, were set at liberty, and the Imperialists gained a town which had been the scene of two disastrous defeats. The chief, Isah, left a fuze burning in a vault of powder under his house, which in the course of the morning blew up, but did little harm.

On the 4th May the force moved towards Quinsan to carry out the original programme, but the soldiers were so burthened with loot that it was found necessary to return to Sungkiong; an Imperialist force under General Ching having stockaded itself off the west gate.

On the return of the force to Sungkiong, a difficulty arose concerning its command. Burgevine after his dismissal had gone to Pekin, and through the intervention of the British and American Ministers, who considered him ill-treated by the Governor, had returned with an edict authorizing him to retake the command; this the Governor Li would not accede to, and the British General Brown refusing to interfere, the force remained under the undersigned.

On the 24th May, the force left Sungkiong for the last time for Quinsan, it having been observed that its discipline would be better maintained in the field than in garrison away from the enemy. Quinsan is a town of great strategical importance; it is situated 40 miles south of Chanzu, and from it diverge large navigable canals. Its possession by a force in command of the waters precluded any hostile advance on Shanghai. It is a city with a wall 18 ft. high and four miles in circumference, and with a very wide ditch. To the north of it, and inside the walls, rises a steep hill 250 ft. to 350 ft. high, with a pagoda on the top. From this the flat country around can be seen on a clear day for thirty miles.



A large canal runs from its west gate to Soochow, the prefectural city of the province; large lakes extend to the north and south of this canal, along the north bank of which runs the only road to Soochow; another road leads from the north gate to Chanzu, then garrisoned by Imperialists. It will, therefore, be seen that if the road to Soochow was cut, the garrison of Quinsan must either surrender or starve. The experience gained at Taitsan shewed that efforts should be made to avoid the costly mode of attack by breach and assault, and to strike at the rebel communications.

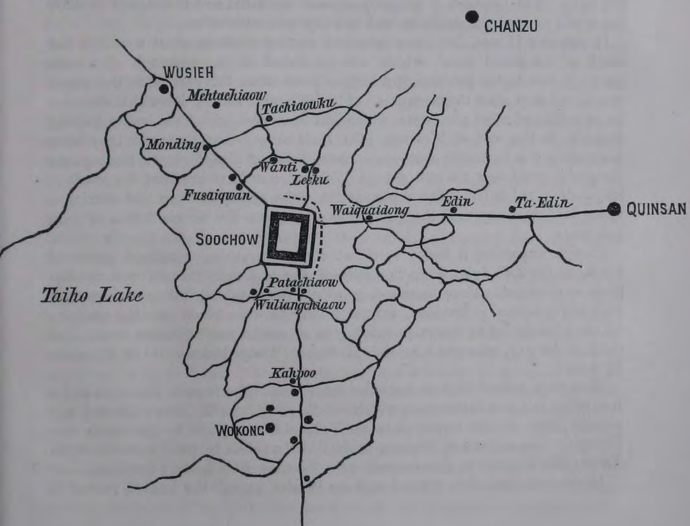
It has been related that the Imperialists under General Ching had entrenched themselves off the east gate of Quinsan soon after the fall of Taitsan, and in the middle of May the rebels had issued out from Soochow and had almost surrounded the Imperialists' position by stockades and breastworks. It was, therefore, necessary to drive these forces back before any further movements against Quinsan could be undertaken. Accordingly, on the arrival of the force at Ching's camp on the 28th May, the rebels were attacked in flank, and after a sharp but short engagement, they evacuated their positions, and retired to the north and west of the city. On the 29th May, the great canal leading round the city and joining the great canal from the east gate of Quinsan to Soochow was reconnoitred by the steamer Hyson; an imprudent proceeding, as it might have shewn the rebels their weak points. This canal joins the other about 10 miles from the east gate of Quinsan, and this junction was defended by two stockades, with the village of Chunye strongly intrenched a little way to the north-east.

At 3 a.m. on the 31st May, the steamer Hyson, 350 infantry embarked on board Chinese gun-boats, and a proportion of field artillery, started for Chunye. The rebels mustered much more strongly than the day before, and replied briskly to the fire of the 32-pdr. on board of the steamer, which steamed up to the stakes that stretched across the creek. A part of the infantry were landed, and advanced towards the stockade, which was on the same side of the great canal as they were, and which was quite isolated. The defenders of this stockade, seeing the steamer pushing its way through the stakes, threw themselves into boats and into the water and evacuated the work, a proceeding followed immediately after by the defenders of the other stockade. The infantry then crossed and occupied it, and leaving a party in it, passed on towards the village of Chunye, which was evacuated on their approach; thus the grand line of retreat was cut, and with only the loss of two men. As the Hyson turned to the left towards Soochow, a large body of rebels appeared coming down from that place to reinforce the stockades; she opened on them with grape and shell, and pressed their rear as they retreated along the narrow causeway; they could not go to the right, for there at no great distance lay the Yangsing Lake, which had large branches running from it to the main canal, over which branches the causeway passed by narrow and high bridges. At each of these bridges delays occurred, and the rebels suffered severely. About three miles from Chunye, a large masonry fort defended the advance, which was taken by the fugitives rushing pell mell into it. A large single arch bridge crossed the canal here, which the steamer, lowering her funnel, passed under, while runaways were crossing over the bridge above. The retreating mass, joined by the garrison of Ta Edin, continued to fly in front of the steamer until Siaou Edin, another strong stockade, was reached, which with another called Waiquaidong was evacuated on its approach. This was a mile from Soochow, whose garrison were evidently in a great state of alarm; but here it was necessary to turn, for it was 7 p.m., and the chase had lasted since 1 p.m.

On its return the steamer met crowds of the rebels whom it had left behind, who opened fire on it, and who met with sweeping showers of grape and canister. The neighbouring villagers flocked down, looted the stockades, and murdered such of the rebels as were lurking about. At 2 a.m. on the 1st June, the steamer passed Ta Edin, and all at once a heavy fire was opened from the stockades which had been captured, mingled with cheers and yells. It was the garrison of Quinsan attempting their escape. It is doubtful how the matter might have gone, had not the Hyson steamed up and delivered a charge of grape into the assailants, who fell back dismayed towards the town, and who eventually to the number of 8,000 surrendered. The remaining part of the force which had been left at the west gate entered the city at day-break. The loss of the rebels was upwards of 4,000 killed by the Hyson's artillery and the peasantry, and drowned in the creeks in attempting their escape.

It was decided to make Quinsan the head-quarters of the force, instead of Sungkiong, which was too far removed from the enemy.

It was now necessary to look to the capture of Soochow, which was admirably situated for having its communications cut off by a force strong on the water. On the east side, the Imperialists, under Ching, held Waiquaidong; on the south, the town of Wokong was wanted to cut off the communications in that direction, and to enable the steamers to get into the Taiho lake to cut off the city to the west; and the town of Wusieh was wanted to cut off the communications to the north: these two towns captured, it would be only a question of time when Soochow would fall.



The force left Quinsan for Wokong on the 26th July, and on the 28th it arrived in face of Kahpoo, where the canal from Quinsan joins the grand canal; this junction was defended by two strong stockades, out of which the rebels fled after the troops had begun to threaten their communications with Soochow. The communications of Soochow to the south and west were now virtually cut, for from Kahpoo runs, from the grand canal, the water-way for steamers into the Taihoo lake; but Wokong was too near Kahpoo for its safety; it might be attacked from both sides and cracked like a nut, though perhaps it would have proved a hard one. It was desirable to take Wokong, so that when captured its garrison would look after attacks from the south, while Kahpoo repelled them from the north.

On the 29th July, after leaving a garrison in Kahpoo, the force marched along the grand canal towards Wokong, and surprised the large bridge over it near the east gate; the rebels rushed out to reinforce a stockade they had some 700 yards from the north gate, but one of the regiments was too quick for them, and following them up, entered the stockade with them. The north and east gates were now closed; on the west was the Taihoo lake; and there was only the south gate to secure in order to have the city. Leaving a regiment at the east and north gates, the remainder of the force pushed on to the south, where the rebels had a large stone stockade, rather too far from the city to be afforded any help. The moment a company crossed the canal and threatened its rear, the rebels vacated the stockade, and the city was surrounded.

It was now 11 a.m., but there remained another stockade about a mile to the south of the grand canal, which was evacuated on the approach of a company; it was on the junction of a large stream from the east with the grand canal, and soon after the occupation of it there came sailing down this stream a large flotilla of rebel gun-boats, which had been dislodged from some out-lying districts to the east of Wokong. On their seeing that the creek they were descending was in hostile occupation, they turned off into the creek leading into the grand canal near the east gate of Wokong, not knowing that the work at its junction had fallen. The regiment let them approach close, and pouring a volley into them captured them all; thus adding to the force's flotilla 35 good gun-boats.

Though expecting a heavy sortie at dusk, everything remained quiet till 4 a.m. on the 30th July, when the gates of the city were thrown open and the place surrendered. Four thousand prisoners were taken, and in this case, as with the prisoners at Quinsan, several hundreds were taken into the ranks to fill the gaps caused by desertion ensuing on successful looting in the town. The chief of the city, who was a brother of Chung Wang, had escaped in the night by a boat.

Thus were gained in four days the rebel communications to the south and a free entry into the Taihoo lake, which cut them off from the west; the east was already held by the Imperialists at Waiquaidong; while to the north was Chunye. The capture of Wokong compelled the rebels to make a detour of the Taihoo lake in order to communicate with the cities they held in the south.

It was now decided to try and capture Wusieh to cut the line of retreat to the north-west, but the departure of Burgevine with 120 foreigners and a small steamer, the "Kajow," changed the aspect of affairs and compelled a more cautious warfare. The Imperialists put garrisons into Wokong and Kahpoo, and the force returned to Quinsan.

Burgevine's arrival at Soochow encouraged the rebels greatly, and led to the chief making a vigorous attack on the Kahpoo position on the 4th August, which the Imperialists repulsed with difficulty; it was sufficiently near success to oblige re-inforcements being sent from the force at Quinsan, which, supported by the steamers, drove back the rebels and their foreigners, and pursued them towards Soochow. They had been very daring, and had brought up a 12 pr. against the stockades, to the ditches, of which they had advanced in their attacks.

Affairs remained very quiet till the end of September, the weather being very hot, and the number of foreigners in Soochow rendering any great flank movement towards Wusieh a dangerous proceeding.

The troops being unhealthy in Quinsan, it was determined to move them to Waiquaidong, and put them under canvas. At the end of September, a move was made which was attended with important consequences; at a place on the grand canal called Patachiaou, about a mile and a half from the south-east angle of Soochow, a large and deep canal leads towards Shanghai; this cut the line of imperialist communications between Waiquaidong and Kahpoo, and if an exit of rebel troops were made in force by this canal, the communications of the force would be jeopardized, and itself exposed to an attack in flank. It was therefore determined to try and capture Patachiaou by surprise, and thus close this exit.

On the 29th Sept., 1863, at 2 a.m., in a drizzling rain, 500 infantry, with artillery, and the Hyson steamer, moved from Waiquaidong towards Patachiaou, the vicinity of which they reached about 5 a.m.; the rebels were completely surprised, and fled from their strong works at almost the first shot. An effort was made, later in the day, by the rebel chiefs of Soochow and their foreigners to retake the position, but it was easily repelled; the foreigners appeared in Garibaldian shirts, but in this instance their efforts did not amount to much. Experience shewed in these operations, that attacks made in wet weather on Asiatics were generally very successful, their minds apparently becoming easily depressed.

On the 1st October, the steamer Kajow, with a cargo boat on each side of her, descended the grand canal, flanked by Burgevine and his followers and a large body of rebels, led by Mow Wang, the chief of Soochow. The Kajow and one of the cargo boats had 12 pdr. howitzers in their bows, while on the other cargo boat was a 32 pdr. The small force at Patachiaou barricaded the gorge of their work, and prepared for defence. The rebel artillery fire was very accurate, and affairs looked doubtful, when the Hyson came round the point from Waiquaidong; this caused the rebels to hesitate, and when they did advance to the assault they were attacked by a heavy fire in flank, from a company which had been placed outside the work, under the bank of the creek leading to the west. They retired, and keeping up a desultory fire for some time, eventually returned to Soochow. During the night they attempted to surprise the stockade, but were discovered at about 700 yards from the work, and gave up the attempt.

Two days after this, Burgevine came down with a flag of truce, and saw the writer of these notes. He professed himself disappointed with the conduct of the rebel chiefs, and willing to come over with the foreigners, and steamer, and artillery, if the men were paid for their service with the rebels; this was agreed to, and Burgevine returned to Soochow; it being left to him to fix his own time.

Things remained quiet till the 12th October, when information was received that the old rebel chief Isah of Taitsan had come up against Wokong, and had entrenched his force off the south gate. The imperialists were greatly alarmed, and requested an expedition to be sent against him. On the 13th October this was done, and his position being attacked in front was taken only with great difficulty, time not allowing a flank movement. The rebels lost but slightly, as their retreat was not molested. Two heavy explosions had been heard from the north of Soochow on the 12th October, and the cause of them was ascertained on the return of the expedition to Wokong, where two of Burgevine's officers had come in with a flag of truce. It appeared that Burgevine, always vacillating, thought he would try and capture the imperialist position at Ta Chiaoku, to the north west of Soochow: this was held by the troops of the Futai, or Governor's brother, who had starved Kongyin, a city on the Yangtze, into submission, and whose force, numbering from 10 to 20,000, had taken up a position parallel to the grand canal, their right being about 12 miles from Wusieh, and their left at Ta Chiaoku.

Burgevine, with the Kajow steamer and his artillery and foreigners, started with the Chung Wang, who had arrived from Nankin. On the 12th October, they approached the position and surprised 35 imperial gun boats, and two large boats laden with powder. Burgevine, whose relations with Chung Wang were not on the best footing, undertook to capture the stockades, upon which he opened a violent fire. He had landed the foreigners for the assault, when a spark fell into a powder case in the Kajow, and blew her bow open. The imperialists, who had already began to evacuate the stockade, saw the steamer sinking, and returning to the loop-holes drove the assaulting party back. Burgevine then retired, leaving the wreck of the Kajow, and put his wounded into the powder boats he captured in the morning. By some accident one of them exploded, and at the close of the day he had lost the steamer and nearly half his foreigners. Chung Wang was so put out at his failure that he ordered him and his party back to Soochow, where they arrived on the 13th, regarded with the greatest suspicion by the rebels This was the account given by Burgevine's officers, who said that if a false attack was made on the next day, they would during it pass over from the rebels. They returned to the city, and on the concerted false attack being made from 40 to 50 foreigners came over. Burgevine, however, was not with them, but on the following day he came out by the permission of the rebels, and thus though some of his party remained with the rebels, the formidable aspect which affairs had assumed no longer existed, and the force was left at liberty to carry out the original programme of cutting off the remaining communications of the city.

On the 23rd October, Wuliungchiaou, a strong stockaded position west of Patachiaou, was taken. On the 26th, another attempt from the south to take Wokong was repulsed with great loss to the rebels; and then turning north, the positions of Leeku (Nov. 1st) and Wanti (Nov. 11th) were captured. In all these engagements the rebels lost heavily, their positions being surrounded and taken before reinforcements could reach them from the city. Their garrisons numbered from 800 to 1,000 strong, but their stockades were narrow, and the 32-pdrs. tore through them from side to side. At Wanti, through a mistake, one column entered on one side as another column came in at the other. The rebels fought desperately, which together with the cross fire of the assaulting troops, caused many casualities. In these attacks an attentive reconnaissance of the rebel works and an overwhelming artillery fire rendered the captures easy. The dates on which they occurred fell almost day for day on the days agreed on—after Burgevine had left the rebels—with the Chinese generals that they should be taken.

The capture of Wanti completed the junction of the forces under the Futai's brother with those under the writer and General Ching, whose troops garrisoned the captured works—the former extending parallel to the grand canal (as has been remarked), from a place opposite, and 12 miles from Wusieh, where his right wing rested to Ta Chiaoku, which his left wing occupied. Ching's right wing rested on Wanti, and extended by Leeku, Waiquaidong, Patachiaou, to Wuliungchiaou, which his left wing occupied; while the steamers and a large flotilla of gun-boats occupied the Taiho lake.

It remained only to cut the grand canal to isolate the city; to do this was a perilous undertaking, as any force advancing towards it was liable to be attacked in flank on the west by the Chung Wang, who held a strong position at Metachiaou near Wusieh, or on the west by a sortie from the garrison of Soochow. It had been arranged that two positions should be captured on the grand canal, viz., Monding and Fusaiqwan; the object of this being to avoid a simultaneous attack on both sides, from Wusieh and Soochow, which might have ensued had only one position been taken. By the capture of Monding and Fusaiqwan, the garrison of the former would face Wusieh, and the garrison of the latter oppose any attack from Soochow. The Futai's brother agreed to throw forward his left wing and garrison Monding when taken, if Ching would bring forward his right wing and occupy Fusaiqwan when taken.

The capture of the Firefly steamer—in the employ of the force—in the harbour of Shanghai, by some rebel sympathisers, on the eve of the force proceeding to the attack of Chung Wang's position at Metachiaou, preliminary to the advance on Monding, upset these plans, and necessitated contentment with the capture of Fusaiqwan alone, the Fatai's brother, in virtue of the non-capture of Monding, considering himself absolved from giving any help.

The position of Fusaiqwan was surprised and taken without loss on the 19th Nov., the rebel reinforcements from Soochow, as usual, coming only in time to be driven back with loss, and thus with the exception of a small country road by the hills near the Taiho lake, the city of Soochow was surrounded.

Ching, however, fearing to be nutcrackered, objected to garrison Fusaiqwan, which necessitated the leaving of the 1st Regiment and some artillery there, a serious diminution of the force, at the time when it needed every man. There now remained the second line of stockades, which extended round the city at the distance of 500 yards from the walls. These defences were very strong: a breast-work ran along the whole front on the edge of a wide creek, and the stockades were admirably placed as redoubts behind it. When the breast-work was taken the stockades could hold out, and the flatness of the general line presenting no salient, and the proximity of the city walls, which mounted several cannon, among which was the 32-pdr. captured at Taitsan, prevented any attempt being made to cut off the rebel retreat.

In the Malakoff, the Russians allowed the front of their redoubt to be in the outer line, a mistake which lost them Sebastopol, for when the outer line was entered, the redoubt was as useful to the French as if they had made it.

From the reports of the foreigners who had come out of Soochow, it was supposed that these works were left weakly guarded at night, and that they could be easily captured by surprise. Accordingly, arrangements were made for a night attack on the nearest stockade close to the east gate. Several significant signs seemed to presage a failure. The attack was fixed for 2 a.m., on the 27th November. At midnight an eclipse of the moon took place, a phenomenon much feared by the Chinese. At 1 a.m. a prisoner, on being questioned as to a lantern on the east gate, declared it to be a sign that Mow Wang was there. The attack, however, took place, and the troops pushed up quietly in boats to the stockade and landed in silence. The creek was passed by a causeway the rebels had left, and it was only as they scaled the breastwork that they met with a volley right in their faces. They pushed on and carried the breast-work, but could not be got to try the stockade, which kept up a heavy fire on them. After an hour or two it seemed useless to persevere, as the losses had been heavy, and the troops were more or less in disorder, so they fell back carrying off the dead and wounded. It appears that Mow Wang knew of the attack, and that he was with his body guard in the stockade. He lost a good many of his best men, and was described as being very much cast down. Several foreigners who were with him were killed.

It was now determined to attack by daylight, and to employ the heavy artillery to break down the works. At 7 a.m. on the 29th November, fire was opened on the works, and the stockade was set on fire; large gaps soon appeared, and at 11 a.m., the assault was made. By some mistake the length of Blanshard's bridge which was put together was found too short, but the troops managed to ford and get across by the broken causeway; and though the rebel resistance was very bold, and Chung Wang who had come down was most daring in leading on his men, the work was carried. Turning to the left, the troops carried the other stockade, and then passing to the right, they compelled the evacuation of the whole outer line, and captured a 24-pdr. howitzer.

Thus fell the second line of rebel works, though costing a heavy loss of life—27 officers being killed and wounded. The rebels lost about 25 stockades in the panic which seized them after the action.

From the captured stockades the city ditch, 300 feet wide, and the walls, 24 feet high, could be seen; and the point of attack was decided on at the north-east angle, where an enfilade fire could be obtained on the two faces. Batteries were thrown up at night to cover the guns, and the Blanshard bridge stretched out by planks and other means to span the stupendous ditch; but symptoms of wavering began to shew themselves in the garrison. Overtures of surrender were made by some of the chiefs, which were suspected by Mow Wang, whom the conspirators slew at the council table, at 2 p.m. on the 5th December. They sent out his head to the Futai that night, and gave up the city on the 6th December. They were, however, treacherously murdered by the Futai on the afternoon of the 7th December.

Large stores and a number of foreign guns were captured in the city, whose fall caused the evacuation of Wusieh, on the 13th December.

The force remained inactive at Quinsan till the end of February, in consequence of the above treachery of the Governor; but though the same was inexcusable, the writer did not consider that the object which the British Government had in view when they allowed him to serve the Imperialists should be allowed to fall through, and, consequently, the force resumed active operations on the 23rd February.

The position of the rebels was peculiar: the shape of the country they held resembled a dumb-bell; in the upper part of which they had Nankin, Tayan, Kintang, and Chanchufu; in the waist they had Yesing and Liyang; and in the lower part they held Changching, Wuchu, Kashing, Hangchow, and several other smaller towns. It will be seen that a vital blow would be struck if the waist were cut through by the captures of Yesing and Liyang, to approach which the Taiho was most convenient.

This plan was agreed on, and on the 26th February the force passing through Soochow and Wusieh reached the north gate of Yesing to the surprise of its garrison. This city lies between two lakes, one on the east and the other on the west. The Imperialists undertook to guard the north of the city, while the force was crossed over to the eastern lake to the south. At 3 p.m. on the 23rd February, a regiment was passed over with artillery and disembarked on the south side of the lake, meeting with but feeble resistance from the rebels, who retired into their stockades. These were followed by the remainder of the force next morning.

On reconnoitring, it appeared that a large deep canal ran south of the city, and 800 yards from it, from lake to lake; over this was a large high stone bridge; the line of this canal and this bridge was defended by breastworks and stockades. It looked difficult to attack, so the infantry were directed to move parallel to it and out of range, to the western lake. With the view of distracting attention and enabling 200 infantry to cross the canal and carry the breastwork unperceived, these men were concealed in boats in a branch creek leading into the canal, and their advance was to be covered with artillery also concealed in the adjacent ruins. The ruse succeeded, for the rebels drew the bulk of their forces off towards the great bridge which they thought was threatened. Through a mistake the troops making a detour, got further off from the city than was intended; and while they were in this position, a large force of the rebel reinforcements was seen wending its way towards the high bridge from Liyang. This force was allowed to pass on to the narrow causeway which, with a wide ditch on each side, led to the bridge. Once on this they could not deploy, and the troops pressing them in rear caused a fearful panic. The rebels at the bridge shut the gates, but the fugitive Liyang reinforcement stormed the position in spite of the fire the Yesing men opened on them. The pursuing infantry entered with them, at the same moment as the 200 infantry pushed across the canal, and carrying the breast-work, turned the position.

By noon the whole of the rebels' positions outside the walls south of the city were captured, the north was already closed, and the lakes prevented any escape to the east and west. At 2 a.m. on the 29th February, the city threw open its gates and surrendered, its chiefs having escaped by boat.

The lake to the east of Yesing is joined by two deep canals with the Taiho lake, and on the most southern of these, Tapuku, the rebels had a cluster of stockades. Some of their chiefs wanted to surrender, others did not, so it was necessary to send down a small force to compel the unwilling chiefs into submission. This small force arrived off the place at dusk, and communicated with the friendly chiefs, who described their stockades to be on the north of the creek, and those of the unfriendly chiefs to be on the south. The attack would have been rather a difficult one, but the flight of the unfriendlies settled the matter.

On the return of this force to Yesing, the Hyson steamer made her appearance, having passed in through the northern canal from the Taiho lake.

On the 7th March the force marched by land towards Liyang; the flotilla, convoyed by the Hyson steamer, proceeding in the same direction, with instructions to feel their left at about 18 miles from Yesing, where it was intended to halt. Through some mistake they did not do so, and the troops, separated from the convoy, for the first and only time during these operations received no rations. On the 8th the mistake was rectified, but several boats went astray and fell into the hands of the rebels.

It was found that the road from Yesing to Liyang to the south made too great a detour, so that it was necessary to move the 3,000 infantry and 4,000 Imperialists across to the northern road, a distance of eight miles, no small operation, as there were upwards of 13 canals from 60 to 100 yards wide to cross over; however, with the help of the gunboats, all was accomplished by the night of the 8th March.

At 9 p.m., some of the boats which went astray into the rebel lines came back with a letter from the rebel chiefs of Liyang, offering the surrender of the city. The Hyson started with 150 infantry at once, and at dawn reached the stockades outside the city. The rebels scarcely expected their arrival so soon; however, they gave over one stockade, and eventually opened the gates of the city. The remainder of the force came up in the course of the day, having had to cross twenty-seven wide creeks, as the rebels had broken all the bridges: and thus the waist of the dumb-bell was cut.

The garrison of Liyang could not have been less than 20,000 men; the chief Shih Wang was next to the Chung Wang in rank. He had gone out the day before to reconnoitre, and had been shut out by the other chiefs, who surrendered as related.

It should have been mentioned that to the west of Liyang were 40,000 Imperialist soldiers belonging to Tseng Qwo Fau, the Generalissimo commanding the forces around Nankin. These troops acted as a covering force to the investment. The capture of Liyang liberated these troops for other duties.

It had already been considered that in the event of success in the captures of Yesing and Liyang, the force should move from the latter city on Kintang and Tayan, and thus cut Chanchufu off from Nankin. Accordingly 1,600 of the Liyang rebels having been taken into the force, about 1,500 men, the artillery, and the "Hyson" started for the capture of Kintang, which, it was expected, would surrender.

On the 18th March these troops marched through a devastated country for Kintang, in the vicinity of which they arrived on the 21st. The city is small and had little cover round it except on the north-east angle, which it was determined to breach. The rebels made little show, and at daybreak the guns were placed in position. Just, however, as they were about to open fire, a courier came in from the Governor of Soochow reporting the irruption of a large rebel force from Chanchufu towards Kongyin and Chanzu; as they had already taken Fushan and were threatening the two former cities, causing great alarm at Soochow and Quinsan, which were only weakly garrisoned, the Governor concluded by requesting the return of some of the force to repel this invasion. The guns being now in position, it was thought better to try and capture the city before returning, and arrangements were made for the assault by placing the men in boats on the creek leading into the ditch of the city. A breach was soon formed and the gunboats started to the assault, when the rebels mounted the breach and opened a heavy fire on the advance; the writer (who went along the bank with the gunboats) on approaching the edge of the ditch saw that the stone bridge over it was unbroken and imprudently ordered a change of plan in the moment of execution of the assault, directing the troops to land, and assault across the bridge. This change of plan gave the rebels courage, and though the breach was thrice assaulted, they repelled each attempt with considerable loss to the assailants. It was, therefore, determined to desist, and to return to Liyang, leaving the 1,000 infantry who had been engaged at Kintang to proceed with a fresh regiment to the attack of the invading rebels from Chanchufu. The Kintang rebels harassed the force very much during the night of the 23rd March, creeping up and throwing powder bags into the boats, but at daybreak they fell back and the retreat was unmolested.

Arriving at Liyang on the night of the 24th, the defeated troops were disembarked, and a fresh regiment with 1,600 of the Liyang ex-rebels who had been drafted into the force, started for Yesing and Wusieh, where they arrived on the 26th March, and where more information was obtained of the rebel invasion which had thrown the country into a regular panic.

It appeared that the rebels had established posts from Chanchufu along south of Kongyin to Chanzu, where the head of the force lay, and as time pressed, it was thought advisable to let their Chiefs know that the troops were still in existence by attacking their communications, which would tend to bring them back and slacken their efforts against Chanzu.

A series of skirmishes near Niukiuchiaow occurred on the 27th and 28th, which tended to bring the rebels back from Chanzu, but as the attacks were made in a direction which might drive them into settled districts, it was thought advisable to move round and attack Waisso—where they had now accumulated—from the east side and to drive them on the Imperialists who had now come from the south and out of Kongyin, and held positions, barring the rebels from returning to Chanchufu; along this line they had broken all the bridges, and thus the rebels were in a complete *cul de sac.*

The regiment of infantry and the 1,600 enlisted rebels were directed to move by road from Liukiuchow towards Waisso on the morning of the 31st March, with directions to feel their right so as to keep up a communication with the light artillery boats which proceeded by water to the east side of Waisso. With the artillery boats was the writer, who was unable to walk from a wound in the leg received at Kintang. At noon the boats approached Waisso, but there was no sign of the infantry, though sounds of firing had been heard in the distance. The rebels perceived the boats, which managed to get back with difficulty to Liukiuchow, to which the infantry had returned in the greatest disorder, seven officers and 450 men, out of 2,000, having been captured and killed. It appeared that the officer in command had been lured on to the vicinity of the rebel stockades which he thought he would take before the artillery came up; his arrangements were so long in being made that, when he was ready, the rebels had large parties out on each of his flanks, on which he began to retire. The retreat soon degenerated into a rout, and the rebel horsemen rode through and through the ranks until close down to Liukiuchow, when the fire of a company of infantry and a couple of guns stopped them. After such a disaster it became necessary to fall back to Siangchow and to send for more troops. The Governor now agreed to garrison Liyang, from which place the force was withdrawn on the 6th April. They arrived at Liukiuchow on the 9th, and on the 11th were moved up towards the east side of Waisso, which was surrounded by 16 stockades; a close reconnaissance shewed that the most northerly stockade was weakly garrisoned, the rebel forces being massed towards the south. By a quick movement a regiment seized this stockade, which turned the rebel position and compelled them into a retreat, soon to be a flight. They were now hemmed in on all sides and had no intrenchments; the Imperialists and villagers hunted them down, and out of the whole of this invading force barely 1,000 got back to Chanchufu. The bodies of the officers and men killed on the disastrous 31st March were recovered and buried.

In spite of the treachery, five cities in the south had surrendered to the Imperialists since the fall of Soochow, and on the 20th March, General Ching, who had got some artillery officered by foreigners, breached and carried by storm the city of Kachungfu, which lies on the grand canal below Wokong He was, however, mortally wounded in the assault; and thus the Imperialists lost the best general they had. Ching was a very brave intelligent man, and would have been a good leader in any country. On the 21st March, the large city of Hangchow was evacuated, after having repulsed an assault made by the Franco-Chinese force.

The force now turned towards Chanchufu which was nearly surrounded by the Imperialist forces to the number of 80,000. It was defended by Hu Wang, a most noted rebel chief, and a large garrison of determined men. A detour was made to reach the west gate, where the rebels had a nest of stockades outside the walls, and some distance from them. On the 22nd and 23rd April, these were attacked and evacuated after a feeble resistance. In the grand canal which runs close to the city, was the wreck of the Firefly steamer, burnt by the Imperialists, when lying at a stockade off the west gate, midway between Chanchufu and Tayan, and which stockade they had surprised.

As the ground admitted of it and time did not press, batteries were thrown up 150 yards from the wall for the breaching guns. These were made at night by the Chinese, who worked admirably and quietly; they were finished by the 26th, and the attack was fixed for the 27th. The Governor wished that the Imperialists should try their hand in the assault at two breaches which had been made at different places in the wall by some foreigners they had in their employ, and that the assault by the foreign officered troops should be delayed till they had tried.

Accordingly the Imperialists made their attempt at 1 p.m., but failed signally. At 2 p.m. the assault of the force took place, a breach having been made in the morning. The ditch was crossed by a bridge of Blanshard's pontoons, but the rebels behaved with such gallantry that they repulsed two attacks, forced back the attacking column, and obliged them to abandon the bridge, which the rebels, during the next night, took up the breach into the town.

On the 9th May the troops and artillery of the late General Ching arrived, and a bridge of casks having been prepared, an approach was made from the batteries to the edge of the ditch, by which the attacking columns could advance to the assault under cover. The cask bridge was boomed across on the night of the 10th of May, and another breach having been made by Ching's artillery, the place was assaulted at both these breaches, after giving the rebels several false alarms by bugle. A party of Imperialists, under Co Sung Ling, attacked with the foreign officered force. Both assaults succeeded, though the rebels fought desperately, and threw the usual amount of powder bags among the stormers.

The 32-pdr. gun taken from the Firefly steamer, lay on the other side of the breach, loaded to the muzzle, and intended to sweep the breach; it had, however, missed fire.

The rebel chief, Hu Wang, was beheaded; but, as a rule, few others fell.

With this action ended the operations of the force, which was paid off and dissolved by the 1st June.

The fall of Chanchufu led to the evacuation of Tayan, on the 13th May; Kintang had been evacuated on the 25th April, and there only remained in rebel possession, Changching, which surrendered on the 4th July; Nankin, which was taken by storm on 13th July, the 42-ft. wall having been blown down for a distance of 150 feet by a mine placed at the end of a gallery driven from a stockade 200 yards from the city; and Wuchufu, which was evacuated on the 28th August, 1864.

In concluding these imperfect notes, testimony must be borne to the gallant behaviour of the brave foreigners, who officered the force. Numbering in all 130, they had 35 killed and 73 wounded; while the Chinese out of 4,000, had 520 killed and 920 wounded. The losses at Waisso raised the number of killed beyond its usual proportion to the number wounded.

The total cost of the force for the fourteen months the writer held the command was about £200,000.

Should any future war with China arise, too much attention cannot be paid to the close reconnoitring of the enemy's positions, in which there are always some weak points; and it is to be hoped that our leaders may incline to a more scientific mode of attack than has hitherto been in vogue. The hasty attacks generally made on Asiatic positions cost valuable lives, invite failure, and prevent the science of war theoretically acquired at considerable cost being tested in the best school, viz., that of actual practice.

C. G. G.

PAPER XIV.

DESCRIPTION OF THE PASSAGE OF THE WET DITCH OF LUNETTE No. 52, AT THE SIEGE OF STRASBURG, BY THE PRUSSIANS, IN 1870.

By Colonel LENNOX, R.E., V.C., C.B.

At the Siege of Strasburg by the German Army under General von Werder, in 1870, the passage of the wet ditch of Lunette No. 52, had to be effected. The counterscarp and escarp were unrevetted, and their slopes about $\frac{1}{2}$; the level of the water was about one or two feet below the terreplein of the covered way, and about the same height above the berm on the escarp side; there was a hedge on the berm. The width of the water was 182 feet; there was a cunette in the ditch about 50 ft. wide; the depth of water at the cunette was 15 ft. to 18 ft., and in the rest of the ditch from 5 ft. to 8 ft.; there was hardly any current. The ditch was flanked by musketry fire from the counterguard No. 51, and from the bastion No. 12, but the lunette No. 52 was not at the time regularly held by the French, though it was visited from time to time by their patrols.

As the passage of a wet ditch is always a difficult operation, I propose to give all the details I have been able to gather of the mode of proceeding adopted on this occasion by Captain Andreae, Royal Prussian Engineers, on whom the duty devolved.

There were not any materials in the Engineer park of which to make a bridge, and therefore such materials as could be found or obtained on requisition had to be made use of. There were in the neighbourhood of Strasburg several breweries, and large barrels could be obtained from them; this led to a decision to cross by means of a bridge of casks. The length of the piers, and their distances apart, were determined in a great measure by many logs 14 ft. long, 8 in. wide, and 4 in. and 6 in. thick, being found at the railway station in course of construction at Schiltigheim.

The following is a description of the bridge: The barrels were from 4½ ft. to 5 ft. in diameter and length, and two were used for each pier, placed longitudinally, with their outer ends 11 ft. apart. On the casks rested a saddle, composed of two gunwales (14 ft. by 8 in. by 4 in.), nailed to two transoms (4 ft. 8 in. by 8 in. by 3 in.); the transoms were 11 ft. apart in the clear, and in their upper sides notches (2 in. deep) were cut to receive the gunwales, which were 18 in. apart in the clear, and had notches (2 in. deep) cut in their under sides to fit on to the transoms. The gunwales were nailed to the transoms by 2 spikes at each junction. On the outer side of each gunwale were fixed four hooks for use in lashing the outer baulks to the gunwales. Each cask was secured to its saddle by one lashing (attached to a staple fixed in the outer side of one gunwale), passed down round the barrel at the bung, and made fast to a staple in the outer side of the other gunwale; the casks being of different sizes were sorted carefully, so that the two in each pier might be of similar size; each saddle was made to fit its own pair of casks by bevelling off the lower inner edge of the gunwales; the staples were fixed at half the length of the cask from the transoms, the ends of the casks thus butting against the transoms. The buoyancy of each pier was observed, and the piers were so arranged that the roadway of the bridge ascended at a somewhat even slope to the centre of the bridge, and then sloped gradually down again to the other bank.

The piers were placed 10 feet from centre to centre; four baulks (14 ft. by 8 in. by 3 in.) were used in each bay; they were notched on the under side in four places, so as to fit securely on to the gunwales of the saddles; the notches were 2 inches deep and 4½ inches wide, which allowed half-an-inch play, as the gunwales were 4 inches wide. Each baulk rested on both gunwales of two saddles. Each pair of outer baulks was secured by one lashing at each saddle; the lashing was hitched on one of the hooks in the gunwale, passed over the pair of baulks, round the other hook in the gunwale, back again over the pair of baulks to the first hook, and then frapped round the three strands between the hooks and the baulks and made fast. The two inner baulks were placed intermediately between the outer baulks, but they were not lashed. The inner edges of the first set of baulks were at the following distances from the centre of the saddle, viz., outer baulks, 4 ft. 3 in.; inner baulks, 1 ft. 5 in. The second set of baulks was inside these; the third set outside the second, and so on. These distances were theoretical, and practically they were judged by the eye.

The roadway was of planks 10 feet long, 10 inches wide, and barely 1 inch thick; the planks were fastened down by means of ribands (3 in. by 4 in.) placed over the baulks and secured to them, in some cases by long screws, and in others by rack lashings. When completed, the roadway was $3\frac{1}{2}$ feet above the water when the bridge was unloaded, and $1\frac{1}{2}$ feet when loaded.

The materials having been prepared, Captain Andreae's, or the 1st Festung-Pionir company of the 1st Army Corps, was, as a preparatory measure, exercised at forming the bridge on the river Ill, in which the stream was known to be not less rapid than in the ditch of the lunette No. 52.

The mode adopted of anchoring the bridge was by cables from every second or third pier, held by men lying down on the bank at intervals; there was however found to be so little current in the ditch of the lunette, that it was not necessary to carry out this arrangement there.

It had been intended to exercise the company by night, as well as by day, but owing to the passage of the ditch having been ordered some days earlier than was originally intended, the men had only formed bridge twice, and both times by day, before they had to perform the duty under fire.

The place selected for the passage of the ditch was immediately in the proper front of the traverse, nearest to the salient of the covered way of the right face of the lunette. The crowning of the covered way of the lunette had been effected several days previously by means of flying sap; the plan, however, of the lodgment was that of the Prussian crowning sap, which is nearly the same as our half double sap, with attached and detached traverses.

On the night of the 19th September the descent to the ditch was made. As the water in the ditch was only about $1\frac{1}{2}$ feet below the covered way, the descent consisted merely in making a cutting from the crowning sap to the terreplein of the covered way; the sides of the cutting were revetted with two tiers of gabions, about 9 feet apart at base. To protect the party employed, a screen of gabions and sandbags was put up on the terreplein of the covered way. The passage between the traverse and the parapet of the covered way was filled up with earth from the cutting.

The cutting was blinded as follows: ground plates were laid on each side, at the foot of the gabion revetment, 8 feet apart in the clear; on each of these were placed four stanchions, and on the top of the stanchions were wall plates; tenons in the stanchions fitted into mortices in the ground and wall plates; the stanchions were strutted; the stanchions were not vertical, but rested against the gabion revetment; the ground plates were prevented from slipping towards the centre of the cutting by pickets driven in front. The roofing was of single headed or flat bottomed railway bars, from 18 to 21 feet long. The flat bottoms rested on the wall plates, but there was a second layer dove-tailing into the first with their flat bottoms upwards. Earth to a thickness of about 3 feet was thrown on the top of the rails. (I may here mention that a shell fell on this roof on the night of the 22nd September, and that it bent some of the rails, allowing earth to fall through; the number of rails bent, and the amount of permanent deflexion I was unable to ascertain. The distance between the bearings of the rails was about 10 feet).

Forming and blinding the descent were all performed on the night of the 19th September. On the same night Captain Andreae had the depth of the ditch roughly ascertained, by a couple of men wading and swimming about in it.

On the night of the 20th September the materials for the bridge were conveyed from the practice ground on the river Ill to the first parallel, in fifty country waggons. The noise made on the occasion attracted the notice of the enemy, who opened fire, which caused several casualties among the horses and men of the convoy.

On the day of the 21st of September the materials were taken by an infantry working party, by hand, from the first parallel, to the lodgment on the crest of the glacis, and stacked there systematically. Experiments had previously been made to ascertain whether the iron hoops would be liable to come off when the casks were being rolled, and in consequence each hoop had been secured by four small nails.

On the night of the 21st September, the passage of the ditch was executed by the 1st Festung Pionir Company of the 1st Army Corps, under Captain Andreae. The other officers were Lieutenant Karl von Keiser, who was stationed between the descent and the bridge, and Lieutenant Julius Schulz, whose duty it was to see that the stores were brought forward in the order in which they were required. One party of men brought the stores from the depôt in the lodgment to the descent, and another party took them from thence to the bridge; this arrangement prevented crowding in the descent which, as before mentioned, was only 8 ft. wide.

Only 50 pioniers were actually employed in the construction of the bridge; the remainder were in reserve to replace casualties, &c.

The screen of gabions and sand-bags put up on the terreplein of the covered way on the night of the 19th September was first removed, and with the materials a gabionade of two tiers of gabions (filled with sand-bags, backed up by sand-bags, and with sand-bags at the junctions of the gabions) was erected, extending from the end of the traverse as far down into the water as possible; this work occupied from half-past 7 to 8 p.m., and as it was being commenced, Captain Kirchgästner, of the Baden Engineers, was killed just behind the traverse.

The formation of the bridge itself was commenced at 8 p.m. The first operation was to get a cable across the ditch; this was effected by a pionier swimming across with a breast line, and then hauling over a cable which he made fast to the hedge on the berm, opposite to the intended central line of the bridge; he then swam back again.

In the meantime four powerful men had been stationed in the water close to the bank as saddle-holders; the first saddle was then brought out of the descent by four men, and carried down (gunwale with the cask lashings attached to it to the front) to the bank; in transit, the cask lashings were cast loose so as to trail on the covered way. The saddle was handed by the four saddle-carriers to the saddle-holders in the water; these men stood outside the four angles of the saddle, facing inwards, and held the saddle with the gunwales on their inward shoulders; (the saddle-holders had the hardest work, and they had two men as a relief).

The two casks for the first pier were rolled down, one after the other, by two men each, placed in position under the saddle, and lashed to it by the cask men.

The two outer baulks were next brought down by four baulk-men, and lashed to the two gunwales.

The second saddle was then brought down by the saddle-carriers, and handed to the saddle-holders, the first pier being boomed out a little, and the ends of the two baulks being raised over the saddle.

The two casks for the second pier were rolled down, placed, and lashed.

The two inner baulks were brought down by four men and placed.

The two outer baulks to connect the second and third piers were brought down, and the two pairs of outer baulks were lashed to the gunwales of the second pier.

Six planks were then brought down and got into position by sliding them along the baulks; the first plank was placed a little short of the first saddle; on the portion thus planted, two men were stationed (lying down), and the cable from the lunette was given to them, by which they kept the head of the bridge straight, and assisted in booming out.

The bridge was boomed out a little, and the ends of the outer baulks raised and placed on the third saddle, which was brought down and given to the saddle-holders.

The casks for the third pier were brought down, placed in position, and lashed.

The inner baulks were brought down and placed.

The outer baulks to connect the third and fourth piers were brought down, and the two pairs of outer baulks lashed to the third saddle; after which 12 planks (two men carried four planks) were brought down and got into position by sliding, and thus the construction of the bridge proceeded.

After four or five piers of the bridge had been completed, straw was passed on to it, and also the ribands which two men placed and secured with screws or rack-lashings; these men worked as much as possible stooping or lying down. No man was allowed on the bridge with his boots on.

Materials had been prepared for 18 piers, but the bridge when completed consisted of 16 piers: that is, 15 intervals of 10 ft. each, and two shore-bays of 16 ft., making up the total width of 182 ft. The baulks of the shore-bays were 21 ft. in length, and they rested on a shore-transom. The object of having the shore-bays longer was to prevent the casks from grounding.

When the head of the bridge had nearly reached the lunette, two men proceeded to cut the hedge down, and to form a footing in the exterior slope for the shore-transom. The shore-bay was carried across by as few men as possible; the non-commissioned officer carried the shore-transom, two men each baulk, and two men five or six planks.

At 10 p.m. or two hours after commencing work, Captain Andreae was able to report that the passage of the ditch had been made. The night was a dark one.

An examination of the lunette was at once made by a party of miners to ascertain if there were any mines, and during the half-hour occupied in the search, steps were cut in the exterior slope.

At 10.30 p.m. a company of infantry was moved across the bridge to occupy the lunette, and a company of pioniers proceeded to form a lodgment in it.

An infantry working party under Major von Quitzow, of the Prussian Engineers proceeded to form a ramp up from the head of the bridge into the lunette; a gabionade was placed on the berm to cover the head of the bridge and the commencement of the ramp.

Captain Andreae then put up a screen between the bridge and the enemy. The screen put up was not bullet proof, but merely consisted of panels of boards cleated together; the panels were secured (by nails) to poles pushed, nearly vertically, as deep as possible into the bottom of the ditch; these poles were steadied by others as struts.

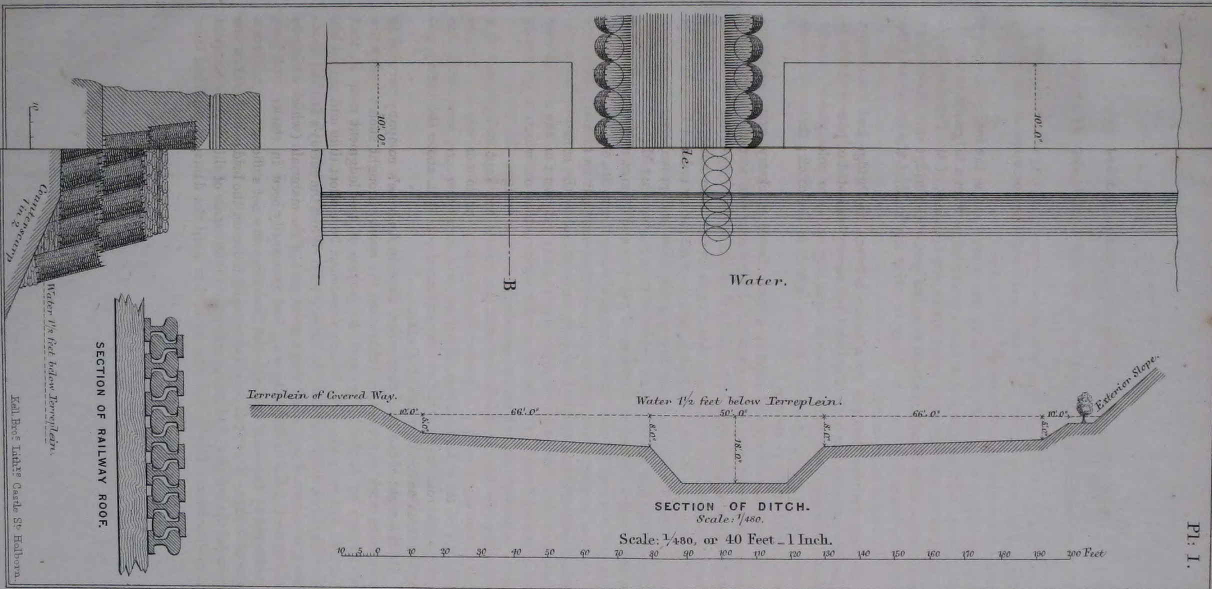
Although the enemy had kept up a heavy fire of musketry, grape, and mortar shells, yet not a single man was killed (and only one wounded) of Captain Andreae's company employed in the construction of the bridge; this was, doubtless, owing to the great care taken to make as little noise as possible, to having very few men on the bridge, and to their being ordered to stoop or lie down. The French musketry fire was too high and passed over the bridge. That the fire was heavy may be judged of from the fact that Major von Quitzow, of the Prussian Engineers, 2 officers of infantry, and 34 men of the pioniers and infantry, were killed crossing the bridge, making the ramp, or in the lunette.

On the morning of the 22nd September, the screen put up to cover the bridge was disarranged and knocked down in many places by the enemy's fire; materials were therefore prepared and brought to the lodgment on the covered way for a second bridge of casks of similar construction on which a gabionade could be made to protect persons crossing the other bridge.

During this day communication with the lunette was kept up by means of a raft of two small boats, which when loaded with 20 or 25 men was only 8 in. or 9 in. out of the water, and was, therefore, in a great measure, screened by the bridge (the roadway of which when not loaded was 3½ ft. above the water), and by the remains of the screen of planks.

On the night of the 22nd September, Captain Andreae's company paraded to commence work at the second bridge, but the enemy brought such a heavy fire of mortars on to the bridge and the portion of the lodgment near it, that Captain Ardreae postponed the commencement for a short time and moved his company towards the salient of the covered way. When the enemy's fire had slackened, he returned and found that a great part of the materials (which owing to the limited space in the lodgment, had necessarily been in stacks) had been destroyed by the enemy's shells, and that there was not sufficient left to form a second bridge. One shell only had actually fallen on the bridge and broken one cask (of the 3rd pier) and its superstructure; the repair of this damage occupied about one hour. The bridge was boomed in until the damaged part had been

Pl: I.



10'. 0".
10'. 0".
le.
Water.
B
Water 1½ feet below Terreplein.
Counterscarp 1 in 2
10
Terreplein of Covered Way.
Water 1½ feet below Terreplein.
Exterior Slope.
10'. 0"
5'. 0"
66'. 0"
8'. 0"
50'. 0"
18'. 0"
8'. 0"
66'. 0"
10'. 0"
5'. 0"
SECTION OF DITCH.
Scale: 1/480.
Scale: 1/480, or 40 Feet _ 1 Inch.
10 5 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 Feet
SECTION OF RAILWAY ROOF.
Kell. Bros. Lithrs. Castle St. Holborn.

removed, and was then boomed out again, as on the occasion of its original construction.

The gabionade at the end of the traverse had also been destroyed; this he likewise made good.

On the night of the 23rd September, Captain Andreae laid a few 2-in. planks lengthwise over the other planks of the bridge, and boarded the bridge over these again; the reason of doing this was that the original planks had bent a good deal; it was also considered advisable to make the roadway somewhat higher out of the water, in case the weight on the bridge caused the casks to sink to the bottom. He also made a screen (not bullet proof) on the bridge itself, slightly to the enemy's side of the centre; it consisted of two tiers of gabions, steadied merely by such sand-bags as were necessary; planks were stood up against any parts where the gabions did not quite touch each other.

On the day of the 25th September, a dam was commenced as a communication to the lunette No. 52, in place of the bridge, on which it was determined to make a bullet proof screen. For the construction of this dam, old gabions, fascines, broken casks, sand-bags, &c , thrown in anyhow were used.

The screen on the bridge of casks was made bullet proof by adding a second row of two tiers of gabions, filled with earth emptied out of sand-bags, and backed with sand-bags; the weight caused the casks to rest on the bottom, but where the cunette was they rested on the dam itself.

The operation of making the dam and screen was proceeded with day and night, but was not completed until the morning of the 27th September; and Strasburg capitulated that afternoon.

W. L.

Before Mezieres,
31st December, 1870.

DISCUSSION* ON PAPER ON DEFENSIVE REFORM.

MAJOR GENERAL SIR F. CHAPMAN, I.G.F., &c., in the Chair.

THE CHAIRMAN: Gentlemen, we are very much obliged to Captain Parnell for the able paper he has read here; and as he says in his concluding remarks, that he has written it with a view to having the subject thoroughly ventilated, I am sure the gentlemen present will be much obliged to any officer who may favour us with any suggestions on this subject either now or at a future meeting, if it is thought necessary or desirable to postpone the discussion.

MAJOR STUART: Captain Parnell has asked us to enter on a large field for discussion, and I do not think it will be possible to cover the whole of it to-night. I am not aware that he has proposed anything novel, except perhaps the detail of his musketry caponier. The subject divides itself into two grand heads. He wishes to do away with excresences, the outworks of fortifications; and also with anything

* Held at the War Office, October 12th, 1870.

in the shape of permanent flanking defence. I think the omission of the outworks is a very serious question, and cannot be disposed of off-hand. I observe that he recommends very long faces for his works, as much as a mile, or 1,600 yards, as a maximum. I therefore conceive, that with such long faces, he will have no difficulty in finding emplacements for any number of guns he would be likely to have to mount; and therefore if he could have those, and also have the ravelins projecting to the front, the addition of those ravelins would it seems to me add very materially to the defence of the works. He would have a much longer siege, and, as time is everything in sieges, he would, I think, give up a great advantage by omitting the ravelins. With regard to his flanking defence for the ditch, I think as an attack on a fortress pre-supposes that the besieger should come up in sufficient force, both in men and guns, to take a fortress, we must suppose that he would work his way to the edge of the ditch, and, working his way there, that he there would have artillery to use. If he is established on the crest of the glacis, and this little flanking "box" were run out, I think in a very short time the flanking defence of the ditch would be entirely gone; it would not only be untenable, but it would cease to exist altogether. I conceive, therefore, that the proposal to place a flanking defence of that particular kind in a work cannot be entertained for a moment. These, as it appears to me, are the chief points for remark in Captain Parnell's paper.

CAPTAIN MARTIN: Would Captain Parnell explain how he intends to prevent enfilading fire along very long faces. I do not understand at all how it is to be prevented.

COLONEL GALLWEY: Captain Parnell has done very good service in bringing forward this question. I had the honour of reading a paper before an Occasional Meeting four or five years ago, and there was a discussion upon it, the notes of which were unfortunately lost. Captain Parnell has stated that he has produced no novelty except the moveable caponier, but he has done great service in re-opening the discussion of this subject. I think the corps wished it; and a great many officers have expressed themselves willing to have the thing opened again. Captain Parnell has spoken of the great importance of direct artillery fire. No doubt the polygonal system is the exponent of direct artillery fire as compared with the old bastioned system, which was broken up into bastions, flanks, and curtains; and I think Captain Parnell has also endeavoured to shew us, that if sufficient attention be paid to the protection of artillery on the ramparts, the enemy could not get near, and that under such circumstances there was less requirement for the ordinary outworks of a fortress than formerly. There is no doubt that the defence has the advantage of being able to supply artillery of much greater power than can possibly be brought into the attack; it has the advantage of protecting that artillery by means of the Moncrieff carriage, or by means of shields or cupolas; therefore I think Captain Parnell meant, that having a sum of money to expend on a fortress, after building the necessary ditch and rampart, he would rather spend the excess of his money in strengthening his artillery than in building the outworks. We know that when once the artillery fire proper is subdued, the fall of the place is a question of time, and a ravelin, or redoubt, or anything of that kind, will only delay it three, four, or five days. We have seen it at Strasburg. There the French have not taken advantage of the modern improvements in artillery and engineering; they have neglected to push out advanced forts, and the siege of Strasburg has been something very like the sieges of a hundred years ago. And the point is this, with regard to the direct fire of artillery, as I took occasion to mention in the Paper I read, that too much care cannot be taken by an engineer in charge of the defence, in clearing away every obstacle on the ground, in fact forming the ground " en glacis " to such an extent, by cutting down hills, filling up hollows, and removing all fences and hedges, that no battery in the besieger's first parallel or in rear of it, can be built without being well seen from the place. If hedges and ditches are left, of course the besieger can throw up and work his batteries with impunity As regards the caponiers, Captain Parnell has taken rather a bold line, but his text is a good one. He says, the fire of a fortress is of two kinds, namely, offensive and defensive ; have your offensive fire strong from the commencement, keep your enemy at arm's length ; keep your defensive fire in reserve till the moment you want it ; therefore his idea is good, if it can be carried out as he proposes. I do not like the musketry-proof box, I would rather have gun-proof caponiers, but his idea is to push them out at the moment they are wanted. Of course there is a great deal of detail to be overcome : the fire from the caponier being very low may be blocked by rubbish ; and the desultory fire of a distant attack will bring down debris from the escarp, which will very likely prevent the running of his caponier into the ditch ; but still the principle is a good one. The length of his faces is too long ; it is very seldom you can get a length of ground like 1,600 yards, that can be flanked from an intermediate or central point. The ground undulates so much, that it forces you to run your lines of escarp and counterscarp parallel to the main formation of the ground, and your flanking points must be arranged accordingly. We have to thank Captain Parnell, as you have done already, for a very good Paper, which will raise a discussion very much wanted in the corps. I would make one remark about the enfilading of long faces, referred to by Captain Martin. If the enceinte of a place is properly designed, viewing the distance at which rifled artillery can attack, for instance in the case of Paris, if those infinite number of bastions were expunged, and the line were straight, it would be very hard to enfilade it. The more numerous the sides or faces within certain limits, the more obtuse the salients, and therefore the less liability to enfilade, as the prolongations fall on ground within easy range of the collateral faces.

CAPTAIN MARTIN : What I particularly referred to was this, that in all fortifications one of the uses of outworks is to intercept the prolongations of the body of the place so that it shall be almost impossible for an enemy to enfilade them. At Antwerp, wherever the ordinary outworks fail to do this, advanced lunettes have been added in front of the salients of the ravelins. Outworks are not needed for this one particular duty when the line of works is straight, or nearly so, but cases will occur in every fortress where a sudden bend becomes necessary, let the fortress be as large as it will, and in these places outworks are indispensable in order to prevent the faces of the body of the place from being enfiladed.

LIEUT. INNES : The general object of the outworks employed in the more ancient fortresses was to obtain this direct fire upon the principal points of attack, which Captain Parnell seeks for ; in the larger modern works, the same object is meant to be attained by temporary works, constructed between chains of forts upon the fronts attacked, should the garrison be strong enough. In any system, taking for granted a perfectly level site, the natural points of attack are the angles of the polygon, and in a small place, fortified on the bastioned or any other system, with only a simple enceinte, you have scarcely any front of fire upon the capitals of the principal angles ; one of the objects of the outworks was to remedy this defect, and obtain the direct fire which Captain Parnell now advocates so strongly. Certainly I agree with him that in the majority of modern instances outworks are no longer suitable to attain that object; what I wish to point out is, that any fortress must, from the very fact of its being an enclosed place, present salient angles somewhere, which will be the points of attack, and that you have to take some means, either by outworks or otherwise, for having fire along the capital lines, on which the attack is sure to come. With regard to the question of direct fire versus flanking defence, that is a question between large well garrisoned places and small, or weakly garrisoned ones; without some means like flank defence, of economising their strength, the latter could not resist at all. Of course no one would attack a place, unless he thought he had sufficient time and means, to reduce it; he would make his calculations beforehand, and attack accordingly, and every attack would then resolve itself into several stages, to overcome the various obstacles, one after the other. The first of these, of course, would be the artillery fire; but there are other steps in the attack; you cannot take a place until you have passed the mines, have descended into the ditch, breached the escarp, and destroyed the flank-defences, and each of these obstacles is quite as essential to be got over, as the direct artillery fire. It, therefore, becomes a question depending on the particular circumstances, whether in any given case, with a certain garrison and certain means at your disposal, you can most advantageously apply resistance in direct fire, or flank defence, or mines, or in any other way. The details of the paper we can, I suppose, scarcely enter upon to-night.

COLONEL RICH: It seems to me Captain Parnell does start a very new theory in the defence of fortresses, and it is this, that he means to resist the first parallel being opened and the first batteries being formed, by bringing upon them an overpowering fire of artillery. Hitherto, at all events, as at Sebastopol, the besieger was generally allowed to open these very easily by keeping at a respectful distance, and the whole force of the attack was employed to resist the besieger at the last—the crowning of the glacis. Captain Parnell directs the whole of his force against the besieger stirring before the place at the beginning, and having done that he seems to think nothing of the last part of the attack. These little caponiers, when the besieger gets to the crest of the glacis, would be no use at all. The subject we have to argue is, therefore, whether he is to be allowed to get near the place at all. If so, I suggest the small caponiers would be of no use. We must have something of much greater importance to trouble the besieger with than small caponiers. I quite agree with Captain Parnell that with the artillery we have at present, it is a very great object to try and overpower the besieger before he opens any batteries against the place at all; but it is very doubtful whether that would ever be accomplished because, as Lieutenant Innes remarks, a General would hardly attack a place without his having means which are, according to his belief, sufficient to reduce the fortress after a siege of more or less duration. With regard to Captain Parnell's long faces, I cannot in the least understand how they are not much more exposed to enfilading than the shorter faces of the old system; and as to the place that has been named – Paris—if at the south-west corner, you turned all the bastions into two long faces, nothing would be easier than to enfilade them from the heights in front of Versailles. At all events long faces are very much exposed to enfilading, much more so than where they are cut up into a lot of small bastions. I cannot conceive how the long faces are not much more exposed to enfilading than the shorter faces.

COLONEL GALLWEY: Longer faces imply a much larger area enclosed.

COLONEL RICH: In all cases you have to get round the circle, and as it is smaller or greater it makes the points from which you can enfilade it less or more numerous. But you seldom get any fort that is a perfect circle, and wherever the points become narrowed to more acute angles, you get those very long faces which are very subject to be enfiladed.

LIEUT. INNES: With respect to the general principle of these caponiers I should be inclined to differ with Captain Parnell, inasmuch as he considers flank defence an extra as it were to be applied on attacked fronts only. We have generally considered flank defence most useful as a means of economising the garrison at other points; in fact, the flank defence, instead of being a mere adjunct upon the front attacked, should rather be a means of economising the garrison elsewhere, so as to leave the greatest number available for active defence upon the front attacked.

COLONEL GALLWEY: Captain Parnell has met that by the training of the Moncrieff carriage. That is his intention, I think.

LIEUT. INNES: In other words he means to substitute direct for flank fire.

LIEUT. COLONEL LEAHY: I think this paper gives an impression of a retrograde movement in the application of engineering to fortification. In the first part of his paper, Captain Parnell correctly describes the aim of the military engineer, which should be to apply a great many different means to produce, within certain conditions, the best possible defensive result. He then advocates a fortified system of artillery instead of the combination of contrivances which an engineer should bring together to produce a scientific system of defence. I do not think the proposal to limit defensive operations to massing a number of guns, which would require large supplies of ammunition and a large number of men to serve them, implies a scientific system of defence. One of the first conditions of fortification is, that there is a possibility of the guns of a fortress being out-numbered and overpowered by those of the attacking force. If the system of fortification be reduced to keeping a number of guns behind a long face, and building in front of them a long straight ditch without any flank defence, beyond the moveable caponiers proposed, the designing of permanent fortifications will no longer offer much scope for the application of the art of engineering; Captain Parnell would almost exclusively limit defensive precautions to the massing of artillery fire; this, I think, is the defect of his paper. By adopting this view we should, I think, abandon much of the business now assigned to military engineers.

COLONEL GALLWEY: There is one thing which Captain Parnell might correct in the paper, and that is the nature of the guns he proposes to use. The 9-in. 12-ton gun and the 8-in. gun are guns for battering ships, and guns of a lighter weight would be more applicable for land defences. You would not arm fortresses for land defence with these 12-ton guns; you would get a lighter gun with a lighter charge, so as to throw an equally large shell with that described by Captain Parnell.

LIEUT. INNES: This is rather a question of detail. The arm of defence ought to be heavier than that brought up to attack; but it is almost impossible to specify calibres, because they are changing every day The general meaning of the paper on this point is, I think, that it is one of the advantages the defence has, and ought to take advantage of, that it can employ heavier guns than the attack

THE CHAIRMAN: It is no object of Captain Parnell's to employ any guns unnecessarily heavy. You only want a large shell gun to destroy the works of besieger; you do not want a gun to penetrate an iron plate. This is a long paper, and I think it would be better if the subject was postponed for discussion at a future meeting, when gentlemen here, and I dare say a great number of others, will have had an opportunity of reading the paper and examining the plans, and going more fully into details than we can do in a couple of hours at an evening meeting.

COLONEL GALLWEY: When the besieger has established his batteries on the crest of the counterscarp to attack the flanking defences, I do not believe that the ordinary caponiers, would last very much longer than the half-inch iron plate. We know that a 64-pound iron shell will go through a 7-foot wall, and burst *en passant.*

The moveable caponiers need not be run into the ditch until the enemy descends into it; but unless they are shell-proof, I doubt if they could be manned. The enemy's batteries on the crest of the glacis could play upon the caponiers while his sappers are crossing the ditch.

COLONEL HUTCHINSON: I suppose that as one great object of all fortresses is to resist attack for as long a time as possible, if Captain Parnell, by this massing of artillery fire upon the ramparts, and doing away with outworks, can produce equally as long a siege as with a fortress provided with outworks, and can do it at the same cost, his fortress may be assumed to be as good as one constructed with outworks. We have been accustomed at Woolwich, in theory, to consider that a fortress, provided with proper outworks, would be taken in about 36 nights if the siege operations were carried on uninterruptedly; that the artillery fire would be subdued by about the fifth night, so as to enable the second parallel and the succeeding works to be carried on without any great hindrance from the artillery fire; that the covered way of the ravelin would be crowned about the 20th night, and that of the body of the place about the 30th So that if Captain Parnell can shew that the increased artillery fire of his fortress would be able to prevent the artillery of the attack from subduing it in fifteen nights instead of five, I suppose that it then might be considered that his fortress would be as good as a fortress provided with outworks. Unless, therefore, he can shew that his artillery fire will prevent the second parallel being constructed for a period of something like fifteen nights from the opening of the trenches, the capture of his fortress would not take so long as that of one provided with the ordinary outworks; and besides this the reserved defence would have been to a great extent sacrificed.

COLONEL JERVOIS: Is the question being considered with reference to the construction of a continuous enceinte, or to the construction of a system of detached works, or to both?

CAPTAIN PARNELL: To all kinds of fortifications.

COLONEL JERVOIS: That is to say, suppose that we were re-fortifying Paris, it would refer to the continuous enceinte and to the detached works outside alike.

CAPTAIN PARNELL: Decidedly.

CAPTAIN MARSH: The chief point Captain Parnell will have to prove appears to be, with regard to the ratio of the number of men in the defence, and the attack, in the system as proposed by him. I have not given the subject much consideration for some time; but when I was considering it carefully at Chatham, I was strongly convinced that the engineering of the present day should be directed to the massing of heavy batteries in given positions inside the enceinte, so as to be able to bring an overwhelming fire on any particular point where an attack might be made, and then to scatter the guns as quickly as possible. In furtherance of that object, I was inclined to adopt a comparatively light gun (a 40-pounder) in order that I might be able to do this and so husband the men and guns of a fortress. But on speaking to men better up in the subject of guns, I am inclined to think I was wrong in taking too light a gun, and that a heavier gun is necessary in order to demolish a besieger's batteries. One of the best opinions we have in the corps was given to me with re-reference to the Moncrieff gun, that on a parapet where ranges can be accurately ascertained, as in a land attack, the Moncrieff gun does not prove the least advantage over any other gun; that it can be hit, shot after shot. Therefore, there will be a great exhaustion of the besieged in the early part of the attack, if they adopt the principle of counter-battering. The besieger has, without question, the power of choosing his position, and bringing a maximum number of guns against the besieged.

The discussion was then adjourned.

ADJOURNED DISCUSSION.*

COLONEL JERVOIS, R.E., C.B., IN THE CHAIR.

THE CHAIRMAN: Gentlemen, you have before you the report of the discussion at the last meeting; and I think it would be desirable before any remarks are made by officers who have not yet spoken on the subject of the paper, that Captain Parnell should say if he has any reply to make with reference to observations that have been already made.

CAPT. PARNELL: I shall be glad to make a few remarks. In the first place, I have received a letter from Sir John Burgoyne, in which he states:—"Colonel "Hutchinson has done me a great favour in sending me a copy of the description of "your new system of Fortification. I congratulate you upon the novelty and inge- "nuity of several of your ideas, which, even if not at once established and adopted, "may give rise to the introduction of improvements in details that may be valuable. "It would be far too great an undertaking for me to attempt to comment on *par- "ticulars* of your various propositions; but, if I read the account correctly, "there is one great difficulty that strikes me in them as a whole, which is, that while "in *theory* they may be correct, they would not *practically* be available, as they "seem to require such an enormous quantity of work to be performed by the gar- "rison, not only after the place is invested, but actually after the front of attack has "been fully declared; at which time the operations of the besieger would become "far more rapid and active than could be those of the besieged. I am somewhat "struck by your idea of a power of running caponiers out and in as occasion might "require, but I fear it would be much too unwieldy on a great scale; a difficulty, "however, that could perhaps be lessened by reducing the size of the construction "in length, or perhaps by running it out in parts like a telescope, one sliding within "another. All these assumed difficulties might, however, be tested by trial and "experiment. I am sure that you will not be offended at my hinting them, and par- "ticularly as they are the result of a very hasty perusal and a first impression which "may have but little reason." I afterwards received another letter from Sir John Burgoyne pointing out that the idea of the moveable caponiers had been already advocated by Colonel Brialmont in his last work. Sir John writes:—"With regard "to your moveable caponiers, it appears from the accompaning extracts that they "have been before *thought* of, which, consequently, you might mention in any future "print of your ideas; but as evidently it was only a slight idea and abandoned, there "will be equal merit in any one who can shew its practicability and advantages." The extracts are from Colonel Brialmont's work on Polygonal Fortification, published in 1869, at Brussels, and are as follows (omitting the foot notes):—"Les "mitrailleurs pourraient être établies dans de très petites caponnières en fer d'une "épaisseur suffisante pour resister au feu de la contrebatterie. On obtiendrait le même "resultat en cuirassant une caponnière ordinaire armée de canons mais la défense "serait beaucoup plus élevée. Dans les petits forts dont le flanquement est toujours "difficile à assurer, et pour lesquels on n' alloue pas en général des sommes impor- "tantes, il serait avantageux de construire des caponnières mobiles en tôle de fer, que

* Held at the War Office, November 23rd, 1870.

"l'on mettrait à l'abri des feux, en les retirant sous des poternes en maçonnerie. Au "moment ou leur intervention deviendrait nécessaire, soit pour repousser une "attaque de vive force soit pour combattre les derniers travaux de l'assiégeant "on les ferait rouler en avant de l'éscarpe sur de forts rails scellés dans des blocs "de granit. Le resultat serait encore plus complet si la batterie cuirassée après "son mouvement de translation etait en état de pivoter rapidement sur elle même," &c. Since the last meeting it has also been pointed out to me that Capt. Schumann, of the Prussian Engineers, has advocated the same kind of caponiers.

I will now advert to certain points which were taken up in the last discussion. The first is the length of the faces, proposed for fortresses. I wish to mention that this is simply a matter of detail, and that I do not urge any particular length for the faces. It is only when circumstances of ground would render it advantageous that I would construct faces of the length shown on the plan.

The second point is the enfiladability of the faces. I submit that this enfilading would be rendered, if not absolutely, at all events practically, impossible, partly on account of the enfilading batteries being subjected to suppression by reason of their necessary proximity to the artillery of the faces, collateral to those attacked, and partly from the unavoidably great flank extension of the field of attack, by which the number of men, and the amount of material necessary to conduct the siege, would be much increased. With regard to outworks preventing faces of a fortress being enfiladed, I would submit that, in practice, outworks would hardly be capable of carrying this out, because the enfilading fire would be sufficiently curved before it reached the face intended to be enfiladed to clear the intercepting outwork. I should imagine that the besieging engineers would have a sufficiently good plan of the fortress, and, partly by that, and partly by means of reconnaisances, would have made themselves acquainted with the prolongations of the faces, and that consequently they would have no difficulty in taking up these prolongations, in spite of any outwork that might intercept them from view; and if this was the case the besieging artillery would likewise have no difficulty in arranging the elevations and charges of their guns, so as to clear these outworks, and yet so as to enfilade the unseen faces in rear.

The third point is the part caponiers should play in forts and fortresses. The theory I advocate is *that no caponier of any kind can hope to resist the enemy's counter batteries when he has crowned the opposite glacis.* Whether the caponier be casemated with earth in front, as Colonel Brialmont proposes, or whether it be iron plated and gun proof, or whether it be a ⅜-inch musket proof carriage, I submit that in no case would it be practicable to withstand the enemy's counter-batteries when he had crowned the crest of the glacis, and I therefore suggest that it is unreasonable to spend money on caponiers with the intention of making them gun proof for the purpose of withstanding these batteries.

LIEUT. COLONEL HUTCHINSON: Do you apply the same argument to flanks of any description.

CAPT. PARNELL: To casemated flanks as well. The fourth point is the theory of the artillery operations in the attack and defence. Colonel Rich, in his remarks, states that I wished to "resist the first parallel being opened and the first batteries "being formed, by bringing upon them an overpowering fire of artillery." Now, I hardly propose to resist the first *parallel* being opened, because I think it would be quite impossible to do so—it would be a waste of ammunition; but I propose to resist the first *batteries* being formed, and to resist their being opened, and to resist them throughout the siege from first to last. In fact, I propose to maintain a strong but judicious artillery fire on the attack from the commencement of the siege to the end. I would not sacrifice the reserved fire, but would make the utmost of my artillery, and would set apart a certain number of guns *to fire only on the approaches*. The rest of the guns of the defence would be, as it were, in support of these *anti-approach* guns, they would try and silence the besieger's batteries which may be considered as supports to the approaches. The besieger's aim is to *approach*, and the defender's aim is to prevent him approaching. With this view the defender should devote all the artillery he can spare, after resisting the approaches themselves, to trying to suppress the supports of the approaches, *i.e.*, the besieger's fire. I would suggest that it would be difficult to lay down any exact time which it might be supposed the besieger would require to subdue the defending artillery. The Woolwich theory, which Colonel Hutchinson mentions, is that the artillery fire would be subdued by about the fifth night, but I presume that is not based on any experience of modern arms or of modern improvements in defence.

The fifth point I wish to notice is that stated by Colonel Leahy. He thinks that the scope of this paper is to impart a retrograde movement to engineering; that because there would be less ingenuity * in designing fortifications, therefore the engineer's art is, as it were, discredited. My hope is that it is enlarged and, so to speak, recredited by the theory now proposed, which is (as mentioned at the beginning) that the art includes not only the application of fortification, but the application of every other means of defence that can possibly be applied, each in its proper place.

The last point is the armament. This paper was submitted about a month before the present war broke out, and it is proposed therein to mount heavy naval guns on the works, at all events much heavier guns than the besieger can possibly bring to bear against the works. Now, in the Paris forts at the present moment, that is just what has actually been done so far as I can see. They have heavy cast iron naval breech loaders of four descriptions mounted on their forts. They have the $6\frac{1}{2}$ inch guns, weighing five tons, throwing a shell of 70lbs.; the $7\frac{1}{2}$ inch gun, weighing eight tons, throwing a shell weighing 115lbs.; the $9\frac{1}{2}$ inch gun, weighing 14 tons, throwing a shell weighing 220lbs.; and the 11 inch gun weighing $21\frac{1}{2}$ tons, throwing a shell of 316lbs. Those guns appear to constitute the armament, at all events the principal part of the armament, of the forts round Paris.

The *Times*, of November 15, in an article from its correspondent at Berlin, dated Nov. 12th, which article gives a succinct account of the different captures of fortresses that have taken place in France up to the present date ends the article, by saying, "Paris being defended by naval guns of great precision and very large calibre, will "introduce an entirely novel feature in the history of sieges." As regards the proportion of garrison to armament, the *Illustrated London News*, of October 29, gives an interesting account from the correspondent of that paper (who it appears is shut up in Paris, and is constantly sending sketches therefrom) about the fort of Mont Valerien. It appears that this fort has 76 heavy guns on the ramparts, and a battery of mitrailleuses, and that its garrison consists of 1,500 Gardes Mobile and 700 sailors. The proportion of the garrison to the heavy guns is thus, 2,200 to 76, as near as possible 30 to one, the proportion I had advocated in my paper.

LIEUT. G. E. GROVER, R.E.: I wish, Sir, to ask one question—not in a spirit of criticism, but in order to obtain information for my own satisfaction. I wish to ask how Captain Parnell would propose to apply his projects to the defence of a great

* I submit that ingenuity is by no means an essential ingredient of engineering.

fortress such as Paris, for example, whose detached works are after all the only fortifications from which the place can expect valid defence. The *enceinte* by itself is of course perfectly useless; and, as engineers do not usually enjoy a level site to fortify, it seems to me rather a waste of our time to discuss here what might be done, with or without outworks, on a level plain, such as the Sahara, whilst we know from experience the true difficulties which stand in our way, and that the first step in properly fortifying a city, or position, is to occupy the commanding heights which surround it. Only this morning, we read in the *Times* that, according to the eminent military correspondent known as our "modern Thucydides," the German scientific corps has expressed the opinion that the French engineers under M Thiers made an extreme mistake in occupying for their detached forts the confined positions which they selected. Yet, we all know that those works were built thirty years ago, when rifled guns were not thought of, and when artillery fire was comparatively in its infancy. Of course, if the military engineers of England or France were, in the present day, called upon to fortify Paris, they would occupy the strong outer line of hills which the German engineers – enjoying a thirty years' additional experience—very properly now say should have been defended by M. Thiers. How then, I ask, would Captain Parnell defend these positions? It is of no use, I submit, for us to discuss abstract theories about systems of fortification upon perfectly level plains. We never have to fortify positions on perfectly level plains. How, I would ask, would the principle of abolishing redoubts and ravelins, and all outworks in a fortress, be practicable in the actual defence of any ordinary position which a military engineer may be called upon to defend? It seems to me, Sir, that as we are assembled here for a practical purpose—not for a discussion of the Woolwich or the Sandhurst system of fortification, or of the proper way of teaching cadets, but to discuss what the engineers of an army should do in actual practice—it would be well if Captain Parnell would explain to us how he would apply his principles to the defence of such a city as Paris, or to any position which may readily occur to his mind as a fit subject for illustration.

CAPT. PARNELL: My intention is not to abolish *advanced* works or *detached* works, but only *outworks*, i.e., what are technically known as *outworks*—works inside the main glacis.

LIEUT. GROVER: All outworks in a fortress except the glacis.

CAPT. PARNELL: I consider the glacis an outwork, I think it is technically an outwork. But I do not propose to do away with advanced works, that is works within musketry range of the enceinte, but outside the glacis; nor, by any means, to do away with detached works. In fact, I give details for detached forts in my paper. I show that long face of a fortress on one of the plans (Fig. 2, Plate 1) simply as an illustration of what you *may* do if you have ground that is available for that purpose. I was obliged to show something or other to illustrate the principles I was proposing; but you may have it of sixteen yards instead of sixteen hundred, it does not affect the principle. The object is to have as little complication as possible, in fact, to make your fortification as simple as possible. The motto I should suggest in carrying out defences would be "Simplicity, Economy, and Sufficiency."

COLONEL RICH: I cannot understand long faces not being more subject to enfilade than short faces, and I will try to illustrate what I mean if you will allow me. Let us suppose that two faces are 600 yards in length, and we put an enfilading battery at 1,500 yards from the salient they form. I say if you divide the length of 1,200 yards into three equal faces, the new face being at right angles to the capital, that the enfilading battery will come rather closer under fire than it was with the longer faces, and if you divide it into five there would be still more difficulty as it would come closer still. Therefore we do not get the advantage of bringing the battery under the fire of the collateral faces by the long faces, and we get the great disadvantage that whilst the battery cannot be enfiladed at all, the enemy enfilades the whole range of 50 guns instead of only a proportion of that number. It seems to me that we are getting back to the old thing. Capt. Parnell now resists the attack the whole way up, that is the old system. I thought his paper certainly started with a view of preventing the first parallel and batteries being established by a superabundant and all powerful ordnance. The third point in his paper seemed to me Guns *v.* Forts as being cheaper. Now he gives us no estimates, otherwise I should be most happy to criticise them, and I think that it would give rather the opposite result, viz., that guns are much the more expensive of the two, especially at the present day when a gun is hardly invented and brought out before a better gun is brought out to supersede it.

THE CHAIRMAN : There is also the cost of ammunition.

COLONEL RICH : That is only when you come to a siege. We are taking now the preparation for defence, not the actual defence ; but even in this, supposing we ordered this large amount of ordnance now, instead of building our works at Portsmouth, probably long before there is any attack on Portsmouth, the guns prepared would have become obsolete and worthless guns, because much better guns would have been discovered ; whereas with works, though there may be improvements and additions, the alterations of the works will cost much less than new guns.

LIEUT. INNES : One principal advantage of a long face is that you thereby economise the flanking defence, and as I understand Captain Parnell, he would not depend much upon the flanking defence. He mentioned just now, with respect to the caponiers that he did not think it worth while that they should be made to resist the direct fire of artillery. I admit that any of the structures you have in the ditch would not be likely to last very long against direct fire, but the strength given to caponiers is rather meant to secure them from vertical fire, and also from dropping shots from a distance—curved fire over the glacis ; of course, if you do not consider your caponiers an integral part of the defence—if you do not depend upon them to secure you from assault—you would not attach so much importance to making them secure. But this, again, is the whole question at issue, for, as I remarked at the last meeting, by adopting direct instead of flanking defence for security against escalade, you do not economise your force for concentration at the point of formal attack ; in other words you are obliged to keep sufficient force always ready to fully man the parapet all the way round, in order to be secure against escalade. The great use of flanking defence is to avoid having to do this, and to enable you to keep yourself secure from escalade with a small number of men on all fronts not attacked by regular approaches. To do this you must make your flanking defences, of whatever nature, secure from distant fire, whether vertical or otherwise.

COLONEL GALLWEY : He does that by hiding them in the escarp.

LIEUT. INNES : He does not propose to put caponiers for flanking defences upon all the fronts ; he proposes only to provide caponiers for certain portions.

CAPT. PARNELL : I state in my paper "The caponiers are not provided until "a time of war is likely to necessitate the employment of these works. Sufficient "material will be placed in store at a time of expected attack, to provide *in fortresses*

"4 caponiers, viz., 3 for the fronts attacked, or collateral thereto, and 1 in reserve; "and *in forts* the number requisite for flanking *the whole of the ditches*."

LIEUT. INNES: Thus in a fortress you would have a large number of the fronts without flanking defence.

CAPT. PARNELL: "In fortresses, the fronts not attacked will depend on their "direct fire for resistance to a *coup de main*."

LIEUT. INNES: Exactly, and that seems a bad way, because you are obliged to fully arm and man your parapets throughout, whereas you might secure unattacked fronts with a small number of guns or muskets, in a flank defence of some kind, and concentrate the bulk of your garrison and material where required to resist an enemy's approaches.

CAPT. PARNELL: Will you allow me to add to what I said before about the theory of caponiers that I advocate, which is, that they are simply required to prevent an accelerated attack, what is called a *coup de main*; that is my idea of the *rôle* caponiers would play in all works. If the besieger chooses to try to approach regularly, and can manage to bring his batteries to the edge of the ditch, I submit that the caponiers then become useless.

THE CHAIRMAN: You only provide a proportion of caponiers.

CAPT. PARNELL: In fortresses, that is on account of economy.

COLONEL GALLWEY: That would depend upon the natural features of the ground. I think you must divide the fire of a place into two classes, viz., offensive and defensive, which ought to be considered as perfectly distinct. I certainly go with Captain Parnell, that it would be better to have your offensive fire so powerful as to keep your enemy at a distance, so that your defensive fire would not be required. Of course that depends entirely on the fact, whether the ground is properly cleared or not. This seems to me the very essence of the polygonal system. I have a few words to say with regard to the artillery. The remarks Captain Parnell made about the naval artillery in the forts of Paris may have reference to what I stated in the discussion at the last meeting. I intended to say that we should not use naval guns for the defence of our own land forts, because we have artillery of equal power as regards firing against earth, which are much lighter and less expensive. I believe the French are rather backward in the matter of rifled artillery. They are still using cast-iron guns, hooped with steel or wrought iron. We have now for instance, as an example, a 7-inch gun of seven tons that would pierce a certain class of armour-sided vessels; and we have a 7-inch gun of four tons that carries a shell containing about eight pounds of pounder, which the other gun does not possess at all. The lighter and cheaper gun is therefore better adapted for the purpose under discussion.

CAPT. MARTIN: It seems to me that Captain Parnell has considerably underrated the advantages of outworks; and also in the matter of economy, on which he so much insists, that he would find his enormous escarp 40 feet high, and a counterscarp to match, would considerably dip into the saving which he proposes to obtain by omitting all outworks. Again, he has, I think, given an outside sum as the cost of a ravelin. The object of an escarp revetment is to give security against surprise and to add to the dead strength of a fortress, so that as many men as possible—as much as possible of the living strength—may be available to meet an enemy when he attempts to mount the breach Another object of an escarp revetment is to force the besieger to use mines or breaching batteries. The revetment of an outwork only meets this latter object. It is unnecessary as a security against surprise. A besieger could have but a very small object in getting into an outwork, unless his approaches had reached the covered way, so that he would be able immediately to connect the lodgment which he might form in the outwork with the rest of his attack, for unless this junction were immediately effected, he would most certainly be driven out again and gain nothing but loss by his adventure. An enemy's approaches having reached the counterscarp of an outwork, an escarp revetment merely causes a certain delay in forming a breach, but answers no other purpose, and, therefore, a ravelin or other outwork may be made to fulfil nearly all its objects at a cost very much less than that calculated by Captain Parnell. I object also to his utter condemnation of all old ideas and systems, because I do not think that it would enter the head of a clever engineer, if he were going to fortify any large site, to do it on any one particular plan or according to any regular system. Skilful irregularity is what he would aim at. He would try to adapt each work as carefully as possible to the features and circumstances of the ground on which it is to stand, and, therefore, use outworks at one place and omit them at another. Hence, also, it seems to me to pit system against system, though a most useful lesson for students of Fortification, can be of no further use, and that the propriety of omitting or using outworks cannot be fixed at a meeting such as this, for their value can only be decided by the ground and other circumstances of each particular case.

LIEUT. COLONEL HUTCHINSON: I think we ought to protest against Captain Parnell's notion that the caponiers and mur des rondes he proposes should be left for construction after a siege has once commenced. It would be very unwise for us to advocate a system, which would put off till the time of pressure, the construction of necessary works of this kind. Some officers who are unable to be present, have requested that this objection may be brought before the meeting, and that the corps may not be considered to approve of the idea. I think Captain Parnell has done well to call attention to the mode of computing the garrison of works, for there are very few data which have been published of late years bearing upon this subject, although I believe the War Office has lately been considering the question.

COLONEL GALLWEY: I will just say one word with reference to a remark of Colonel Hutchinson at the last meeting, which struck me as very apposite to the question, that is—"I suppose that as one great object of all fortresses is to resist attack for as long a time as possible, if Captain Parnell by this massing of artillery fire upon the ramparts, and doing away with outworks, can produce equally as long a siege as will a fortress provided with outworks, and can do it at the same cost, his fortress may be assumed to be as good as one constructed with outworks." I believe that to be the kernel of the whole thing—that if a fort be armed with properly protected heavy artillery, commanding ground to the extent of 2,000 or 3,000 yards, on which an enemy cannot obtain cover, outworks will not be required.

THE CHAIRMAN: In a great measure, I agree with the observation made by Captain Martin, that however interesting and useful for education discussions on abstract systems of fortification may be, such systems, at all events in our case, rarely come into operation. I know of no place which we have been fortifying—and we have fortified a good number during the last ten or twelve years—to which the principle of faces of 1,600 yards in length could well have been applied; indeed there is only one place where we have constructed a new continuous line of fortifications, that is at Hilsea Lines. We have usually employed, and wherever we apply land fortifications, shall probably generally adopt, detached works, to occupy the main points of a position taken up for the protection of a place. I proceed then to what appear to be some of the more practical considerations which are dealt with in Captain Parnell's paper. I may make one remark at starting, viz., that the title of the paper, "Defensive Reform," is rather startling, and it appears worth consideration whether, supposing it to go beyond these casual meetings, the title might not be altered with advantage. The majority of the points referred to in the paper have been, in many cases, actually acted upon. The section of the work proposed is precisely taken, except in its exaggeration, from the works at Portsdown Hill, Staddon Heights, and elsewhere. The ditch is deeper and wider than at those places, but I think the increased width and depth unnecessary. Captain Parnell considers his section an economical one, but, of course, it cannot admit of question, that a ditch 50 feet deep, as he proposes, would be more expensive than one 30 feet deep. Then as regards the mode of mounting the guns upon the works. I believe the plan of mounting guns on the Moncrieff principle, in works of land defence, is a good one ; it is one which, when lecturing on the subject more than two years ago, at the United Service Institution, and before the Moncrieff principle was taken up by the War Office, I proposed as the best system that could be adopted for mounting a large portion of the armament of land works. This system does not, however, give security against vertical fire, and I think it would be desirable to supplement it to some extent with a few guns having bomb-proof cover over head, and iron shields in front. There would thus be some pieces absolutely secure both against vertical and against direct fire. I have brought this drawing to show the meeting that it has already been proposed to carry into effect the principle of applying the Moncrieff system of mounting guns on works intended to resist land attack. The proposal I refer to was made by me nearly three years ago. So far then as regards the principle of mounting guns on the Moncrieff system, it appears to me to be one that should be adopted in land works of defence. As regards the description of caponiers proposed by Captain Parnell, I confess I entirely agree with Colonel Hutchinson and some other officers who have observed on that head. It does seem that when the expense has been incurred, first of buying the land for the position to be fortified, and next for the construction of effective works thereon that it would be a great mistake and one not really conducive to economy, to omit the caponiers. Our caponiers, as constructed, afford absolute security against assault; being well sunk, they cannot be destroyed by the enemy's fire. There would be a good reason for employing the moveable caponier in positions where the fixed caponier would be liable to be destroyed ; but, in the majority of cases in our new works, the fixed caponier cannot be hit till the enemy arrives at the edge of the ditch. I quite agree with Captain Parnell that when the besieger does get to the edge of the ditch no caponier will stand. What you have to do, as Lieutenant Innes remarked, is to protect the caponier against vertical fire, and to sink it well, or cover it thoroughly, so as to protect it against "lobbing" fire. So far as the sides of the caponier are concerned, if they are well sunk, it is unnecessary to make them of great thickness. The permanent caponier is a habitable casemate which will afford accommodation for part of the garrison—an advantage which the small moveable caponier would not possess. Captain Parnell advocates that the designs of our fortification should be as simple as possible. On this point I entirely agree with him. Our works would be almost assuredly manned by comparatively undisciplined troops, and the more they are constructed so that men shall fire to their front and not have to consider whether they are flanking some curiously constructed outwork on the old principle, the more likely the defence will be vigorous and effective. As a matter of fact we do not provide outworks, so we have already adopted that part of "defensive reform" which Captain Parnell advocates. There is a remark which I ought to have made earlier, viz, with regard to the opening paragraph of Captain Parnell's paper, where he observes that it is the engineer's business to consider the professional questions with which he has to deal, in connection with the requirements of the other branches of the service which would have to take part in the defence of the fort; he should also carefully weigh the part which the fort should play in the general defence of the position. It will often be found that a project for a fort very admirable in itself, and possessing most perfect defensive capabilities, is not well adapted and involves unnecessary expense, for the position it occupies. With reference to the armament of land forts, the guns lately mounted in the Paris forts were naval pieces from ships or from sea defences of maritime fortresses, and I believe the reason such large pieces were used was because they were the only ones available. I believe it to be unnecessary to go to the expense of such great guns for works to resist attack by land; with a 7-in. breech-loading gun, with a double shell which holds a large charge, you can produce a quite sufficient effect on earthworks, and I do not know that it is necessary to go beyond guns of this description. Whether that is the case or not, the expense of providing guns which, with only 50 rounds of ammunition apiece, would run you into an expense of at least £1,300 each, would put them out of the question at present for land forts. Indeed, it is difficult enough to get great iron-clad-piercing guns for our sea-forts and for the defences of the coast, and you have to consider those before providing such guns for the armament of land forts. The 9-in. and 10-in. guns which Captain Parnell refers to, were originally proposed with a view of piercing iron-clads, and not with reference to land operations. With regard to the garrison, Captain Parnell's proposal for a garrison of a fort seems reasonable, perhaps rather in excess for a work of 25 guns. My calculation is that a work of the character Captain Parnell refers to would take about 600 men, infantry and artillery; I think that would be sufficient for it.

CAPTAIN PARNELL: I should like to make a few remarks in reply. In the first place I wish to submit that the length of the faces and the depth of the ditches and all those details are not part of any "system" proposed by me; they are quite secondary; what I advocate are principles. And in the next place, as regards the heading of the work, "Defensive Reform," I do not intend by that to assert that I am a reformer: what I wish to bring to the minds of those who read the paper is that the object of it is to consider the effects of certain changes, independently of the question of the inventor or proposer of these changes. For instance, take the Moncrieff gun-carriage, surely the application of that principle is a "reform" in fortification. I presume no one will imagine that reform is the same as revolution. My idea of reform is that which tends to purge away all the dross and abuses and things that are obsolete in a system or institution or anything else, and which tends to conserve all that is good and sound. That is why a great many of the points alluded to by me in the paper are not novelties. I take care to state at the end of the paper "that by no means all the suggestions contained in the foregoing paper "are set forward as novelties." As regards the use of the word "system," I do not propose any "system" of fortification at all; what I wish to do, is simply to advocate certain principles, in fact, you may sum up the principles I advocate in one sentence, or rather question: *Is not the sword of more importance in defence than the shield?* The moving caponiers I consider as simply means to carry out certain ends. I would just as soon have fixed caponiers if it can be shown that they will act as well*, or ditches thirty feet deep if they do better than those of forty or fifty feet deep.

THE CHAIRMAN : Whatever criticism has been passed with reference to this paper, it is no *façon de parler* to say that we are much indebted to Captain Parnell for the trouble he has taken in preparing it, and for the attention he has given to the subject on which it treats. The discussion of propositions such as those we have been considering, whether we agree or whether we disagree with them, must be of use to us in the conduct of the business with which we are entrusted. The more these things are ventilated, the more likely we are to carry on the work we are called on to perform with advantage to the country and with credit to the Corps.

APPENDIX TO PAPER ON DEFENSIVE REFORM.

I. "The engineer is, or should be, entrusted with the *defence* of a place." (See page 31).

I have been requested to explain this sentence. The following is my explanation. I look on defence generally, whether in the field or in previously prepared positions, as a branch of military engineering. But, inasmuch as all power and authority emanates from the General or Senior Officer, the Engineer becomes the agent of the General or Senior Officer, in fact, his Staff Officer, or representative, for conducting defence, on the same principle that the Quartermaster General is the General's agent for conducting campaigning movements, encampments, &c.

II. "Both in *fortresses* and detached forts," &c., (see line 5, page 33). By the term *fortresses* wherever used in this paper are meant "fronts," or "enceintes," or "lines" of fortification. Probably these will not be much constructed in future ; still with the examples of the new Antwerp enceinte and the new Hilsea Lines before us, it cannot be said that such works are altogether obsolete.

III. "*Very heavy artillery*, such as the 8-in. and 9-in. muzzle-loading rifled guns, for the armament." (See page 33.)

The term "*Artillery throwing very heavy shells*," would be more appropriate.

IV. "The number of heavy guns should equal $\frac{1}{40}$ of the combined length in feet "of the three longest adjacent fronts or faces *likely to receive attack*." (See page 42).

By "*attack*" is meant *direct* or *oblique* artillery fire, but not enfilade or reverse fire ; and it is assumed that the work is built on polygonal principles, *i.e.*, that the salients of its faces form obtuse angles.

V. "The number of *rounds of ammunition* furnished will be as follows," &c. (See page 43).

In this paragraph only *projectiles* are intended, the arrangements for *charges* are specified in the next paragraph.

A. P.

* Have caponiers of any sort ever been tried in war ? If not, I submit that they are all equally in the region of theory.

END OF VOL. XIX.

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