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PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS.

CONTRIBUTED BY OFFICERS OF THE ROYAL ENGINEERS

AND

HON. EAST INDIA COMPANY'S ENGINEERS.

NEW SERIES.

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PREFACE.

The principal operations of the late war having been described in former volumes of this series, with the exception of the Siege of Sebastopol, (the journals of which we may hope soon to see in another work,) there remains but little material for these Papers except reflections on the best means of executing works during peace, and preparing, whilst time is granted to us,

entertained on that subject by those who have constructed the most extensive works of defence during the last thirty years. It will also shew how dependant every branch of the service is upon the others, and that without the hearty co-operation of all, no great results can be obtained. Of this the Defence of Sebastopol is a good illustration, for it could not have been protracted as it was without the science, forethought, and energy of an Engineer like Todtleben, the perseverance of Infantry like that of Russia in entrenching themselves, the skill and coolness of her numerous Artillery, and the untiring zeal of her Riflemen; whilst it was only by availing themselves of the power of rapid movement which Cavalry possess, that her Generals could hope to cut off the communication between the besieging army and Balaclava.

P. J. BAINBRIGGE,
Lieutenant-Colonel Royal Engineers.

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The Table shewing the result of the experiments on the penetration of rifle-bullets into various substances, lately carried on at the Royal Engineer Establishment at Chatham, will be especially useful in enabling us to judge of the powers of the new arms, and the Paper on the "Improvements in Fortification" has been translated in order to draw attention to the views entertained on that subject by those who have constructed the most extensive works of defence during the last thirty years. It will also shew how dependant every branch of the service is upon the others, and that without the hearty co-operation of all, no great results can be obtained. Of this the Defence of Sebastopol is a good illustration, for it could not have been protracted as it was without the science, forethought, and energy of an Engineer like Todtleben, the perseverance of Infantry like that of Russia in entrenching themselves, the skill and coolness of her numerous Artillery, and the untiring zeal of her Riflemen; whilst it was only by availing themselves of the power of rapid movement which Cavalry possess, that her Generals could hope to cut off the communication between the besieging army and Balaclava.

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PAPER I.

Report on the Demolition of a Portion of Old Rochester Bridge by the Royal Engineers, in the Winter of 1856-7, Conducted by Capt. Schaw, R.E., under Colonel Sandham's directions.

A new iron Bridge having been constructed over the Medway, at Rochester, in lieu of the old many-arched masonry Bridge, which has for so long a period obstructed the navigation of the river, Mr. Wright, the Civil Engineer in charge of the Bridge works, was directed to remove the old Bridge. This was built 466 years ago on the site of a wooden bridge; and it may here be stated that a code of regulations records that a bridge existed A.D. 1115, on the site of the new iron bridge completed in 1856, which had nine stone piers and ten openings; the width of the road over it was about ten feet; the piers were 43 feet from centre to centre, the road was supported by beams and planks, and a wooden tower stood at the Rochester end of it. In 1264 the wood-work was burnt by the Earl of Leicester when opposed to Henry III. and acting against Rochester Castle. In 1281 ice carried away some of the piers and damaged the others; a perfect passage was not restored till 1344-5, when a barbican and draw-bridge were added at the Strood end. In 1347 the wooden bridge seemed unsafe, and Sir Robert Knollys and Sir John de Cobham provided the means of building a stone bridge which was commenced about 40 years afterwards.

For the purpose of removing that part of the old bridge which was above low water mark, centreings were placed under the second and third arches at the Strood end of it, and the latter were taken to pieces gradually and removed, together with the upper portion of the pier on which they rested. The work had advanced thus far when Colonel Sandham, Director of the Royal Engineer Establishment at Chatham, regretting that so valuable an opportunity for experiment and instruction in mining should be lost to the Corps, with the approval of the Inspector-General of Fortifications, obtained the sanction of the Bridge-wardens for the demolition of a portion of the old bridge by gunpowder, subject, however, to the concurrence of their civil engineer in the plan of operations.

The arch at the Strood end of the bridge, with its abutment and pier, and the isolated pier from which the two arches had been removed, as above described, were the portions placed at the disposal of the Royal Engineers, the only condition being that the masonry was to be dislocated as quietly as possible, so that the mass of debris should fall on the starlings, in order that it might not impede the navigation of the river, or dam up the stream.

The objects contemplated in undertaking this work were threefold, namely,—1st. to practice both men and officers in mining. 2nd. To ascertain the rate at which shafts and galleries can be excavated in masonry, and the details of the best mode of execution, as well as the quantities of gunpowder and other materials required for blasting. 3rd. To confirm the rules already deduced from experiments by General Sir Charles Pasley for calculating the charges necessary to effect demolitions under certain conditions, and also to discover the effect produced by firing the charges under a considerable body of water.

The construction of old Rochester Bridge is peculiar. The arches were originally only $16\frac{1}{2}$ feet wide measured on the soffit. They were of the Gothic form, each arch having five ribs of cut stone, over which the arch sheeting of small irregular stones, averaging eight inches in depth, was built. At a subsequent period the bridge was widened about 12 feet, by the addition of a segmental arch of cut stone, six feet in width, on either side of each arch. The voussoirs of these more modern arches are two feet in depth, with projecting key-stones two feet four inches in depth. See Plate 1.

The piers are very massive, being 20 feet in thickness, and are faced with ashlar, cramped together with iron, and the beds and vertical joints are run with a resinous cement. The interior of the piers and abutments is solid rubble masonry, the stone being Kentish rag, and the mortar, though not particularly hard for such old masonry, forms nevertheless a remarkably tough and solid mass; and it is worthy of remark that the ashlar facing has no bond stones extending into the rubble masonry, but consists entirely of *stretchers*.

The foundations of the piers and abutments are formed of piles driven as close together as possible, and sawn off at about four feet above low water mark of spring tides. There are upwards of 1,000 piles beneath each pier. Heavy flags from nine inches to one foot thick rest on the heads of the piles and support the masonry.

Around each pier a timber starling is constructed, extending from seven to eight feet beyond each side of the pier, and running out 25 feet beyond the cut-waters. These starlings are formed by a row of sheeting piles, protected by three inch planks on the outside, the space between the sheeting piles and those forming the foundation of the pier being studded with piles placed from one to three feet apart: heavy sleepers are spiked down to them and to the waling of the outer sheeting piles, and the whole is filled in with stones, chalk, and clay, and planked over. The whole of the timber used in the foundations and starlings is elm, and appears to be in a very fair state of preservation. The level of the tops of the starlings is from five to seven feet above low water mark. The starling of the pier of the terminal arch is continued throughout under the arch to the abutment, and extends along the river wall for some distance both ways. See Fig. i., Plate 1.

The effect of the starlings on the bed of the river, (by narrowing the water-way, which would have been quite insufficient even if they had not existed, owing to the great breadth and number of the massive piers) is very remarkable. The soundings at low water show a depth of seven feet in the channel between the centres of the starlings, while at the points of the starlings the depth of water is 25 feet. It would appear that the main stream, rushing through the narrowest part of the channel with great velocity, has not so much effect in hollowing out the bed of the river, as the eddies which are produced by the meeting of the currents at the ends of the starlings.

Project of Demolition.

The Abutment. The thickness of the masonry of the abutment was unknown, and two charges were at first intended to have been placed 10 feet in rear of the face, but the line of least resistance was subsequently fixed at nine feet. The charges were calculated at one-fifth of the cube of the line of least resistance, as for a revetment with counterforts—150lbs. for each charge—total, 300lbs. They were to have been placed with a two-lined interval, but on a careful inspection of the masonry, it was observed that the wing-wall on the up-stream side was loosely built, and the charge on this side was therefore placed eight inches nearer to the centre line of the bridge.

The First Pier.—In the pier supporting the arch two charges were placed with a central interval of 16½ feet, and each with four equal lines of resistance of 10 feet, viz., one to each side of the pier and one to each slant face of its cutwater. General Pasley's rule for this case is "Use charges of one-third of the cube of the line of least resistance, at two-lined intervals," but, as the interval here was considerably less than twice the line of least resistance, the charges were calculated at one-fourth of the cube of the line of least resistance, and 10lbs. were added to each, 260lbs. being contained in each charge, the total was 520lbs. The charges were in both these instances placed at the level of the tops of the starlings.

The Isolated Pier.—It was at first intended to have placed two charges in a similar position, only at a lower level, in the isolated pier, it being considered probable that the masonry extended at least down to low-water level; when however the shaft had attained a depth of 9 feet 6 inches it was discovered, by sinking a jumper-hole down to the piles, that the masonry extended only 2 feet 6 inches below the bottom of the shaft in this pier, and it therefore became necessary to adopt some other arrangement for the charges. It was not thought advisable to sink the shaft lower, or to place the charges lower than at 2½ feet above the bottom of the masonry; this left a thickness of masonry above them of only 8 feet 6 inches, and it was supposed that the effect of the water covering the mass of masonry would be to throw the lines of least resistance rather upwards; hence a lateral line of least resistance of 7½ feet was determined upon as being the greatest admissible, which proved to have been correctly decided. Six charges were placed in this pier, two at each end, with lines of least resistance of 7½ feet, and two in the centre, each with lines of least resistance of 6 feet. All these charges were calculated at $\frac{3}{20}$ths of the cube of the line of least resistance. There were here four charges of 60lbs and two charges of 30lbs., making a total of 300lbs.

The Arch.—In order to remove the thrust of the arch, and with it the tendency of the pier to be overturned outwards into the stream, and also with a view to ascertain the possibility of destroying an arch by this means, a number of blast-holes were sunk in the key-stones of the arch, the simultaneous explosion of the blasts in which it was hoped would blow out the key-stones, and throw down a portion of the arch. From the previous description of the arch, however, it will be observed that it was one singularly ill-suited for this economical mode of demolition. The old arch had no regular key-stones, and the peculiarity of its construction made it very difficult to select stones for the blast-holes; fifteen blast-holes were, however, formed in this central portion of the arch, five of which penetrated into the ribs beneath; and for the demolition of the more recently built additional arches on either side of the old one, as before described, six holes 1 foot 6 inches deep were sunk in the key-stones, one in the centre of each key-stone. The charges for the holes, 1 foot 6 inches deep, were each four ounces, and for the shorter holes three ounces: total, 5lbs.

Execution of the Shafts and Galleries.

The party employed throughout the operations were marched down after the first working parade, and their dinners were sent to them. Sergeant Stacey, R.E., was permanently detailed for this duty, and his party consisted of three non-commissioned officers and eight men, with two blacksmiths for repairing tools. An additional party of twelve men was employed for a few days in procuring the clay used for tamping the mines.

The shafts in the abutment (No. 1) and in the pier (No. 2) were both commenced on the 24th of November, 1856, but as the work done on this day was only sinking the shafts each three feet deep through the road-metal and concrete bottom down to the masonry, it is not to be taken into account, and in the subjoined table No. 1 shaft is considered as 18 feet and No. 2 as 21 feet deep, although the latter was in reality 24 feet deep, and the former 21 feet. The galleries branching to the right and left from the bottoms of the shafts were both carried on simultaneously, as soon as there was room for two parties to work in them; and this has been taken into account in the Table also, the length of one gallery only of each shaft being mentioned in calculating the time of execution. In the isolated pier (shaft No. 3) the work was so much retarded by the water that no fair result can be deduced from the rate of progress attained in sinking the shaft, which was moreover worked by unskilled miners at first. After this shaft was half finished a dam of brick-work in cement was built round it sufficiently high to keep out the water at the highest tides, and the remainder of the shaft and galleries may be considered as having been executed at a fair average rate. The necessity for building this coffer-dam arose from the upper portion of the pier having been unfortunately removed below high water level, before it was placed at our disposal. It was built $2\frac{1}{2}$ bricks thick for the first foot in height, two bricks thick for the next five feet, and one brick thick for one foot more, making a total height of 7 feet. It was plastered outside with cement. See Pl. 1.

The unusually heavy rains which fell on Sunday the 11th of January, 1857, caused such a flood in the river as to make it rise four feet higher than the highest ordinary spring tides, and to overflow the brick dam, filling the shafts and galleries with water, and four or five hours were lost on the morning of the 12th in pumping out the shaft and galleries; this time could ill be spared, as 2·30 p.m. on Tuesday the 13th was the time fixed for the explosion. By working all Monday night, however, the mines were loaded and tamped, and everything was completed in time.

In forming the chambers for the charges II. and III. in the isolated pier it was found impracticable to execute them as intended, the portion of masonry between the chamber and the shaft being blown out by the blasts, as shewn by the dotted lines $x\ y$, Fig. 2; and this made the tamping barely sufficient for these charges.

Details.—The jumper or borer was used as found to be most convenient in the excavation both of the shafts and galleries, and the $1\frac{1}{2}$ inch bit was used with the most satisfactory results.

The blast holes were generally from 2 feet to 2 feet 6 inches or 2 feet 9 inches deep in the shafts, and from 1 foot to 1 foot 9 inches in the galleries.

The charges were calculated at $\frac{1}{10}$ L.L.R^3, on an average, though considerable allowances had to be made for the position of the holes, considering whether the masonry was bound on all sides, or was more free to move in one direction than another. Wherever a large stone projected, which was to be split off by a blast, a charge of $\frac{1}{20}$ L.L.R^3 was found quite sufficient, but in holes in the bottom of a shaft, where the line of least resistance was necessarily in the direction of the tamping, from $\frac{1}{10}$ to $\frac{1}{8}$ L.L.R^3 was required to lift the masonry, the line of least resistance being measured from the centre of the charge. The tamping was in all cases broken brick, which answered admirably, only two cases of its blowing out having occurred during the operations, and it may be remarked that it was found better not to pound up the bricks very fine. A wad of oakum was placed over each charge to prevent accidents.

Where the shafts and galleries were wet, the charges were placed in cartridges of brown paper, made up with tallow instead of paste, the Bickford's fuze being inserted into the powder, and the case well choked at the top; this plan answered perfectly, even when the holes were full of water. Three turns of brown paper were generally used in making the cartridges.

It frequently happened that the explosion from a blast took effect downwards, the gas escaping through the mortar joints and forming a large irregular chamber at the bottom of the hole. In such cases the tamping of the hole was jumped out, and from 10 ounces to 16 ounces of powder poured into the chamber, the whole being then re-tamped and the charge exploded, which produced very good effects.

In sinking the shafts, the depth of the blast holes depended on the thickness of the beds of masonry, it being necessary to penetrate through one bed down to the surface of a solid bed below. Deeper holes were tried, but were found to be impracticable, as the jumpers got jammed in the joints of the masonry.

Rope mantlets were used throughout the operations to lay over the mouths of the shafts, being supported on an old gate or rough frame of wood to prevent stones flying from the blasts.

TABLE OF DETAILS OF EXECUTION OF SHAFTS AND GALLERIES.

Number of Shaft or Gallery.	Depth of Shaft or length of Gallery in feet.		Total hours employed in the execution.	Total number of blasts fired.	Total quantity of Gunpowder used, in lbs.	Total quantity of Bickford's Fuze used, in feet.	Rate of sinking Shaft or driving Gallery in inches per hour.	Number of Blasts per foot in length of Gallery or depth of Shaft.	Charge for each Blast in ounces.	Gunpowder in lbs. used for each foot in depth of Shaft or length of Gallery.	Bickford's Fuze in feet used for each foot in depth of Shaft or length of Gallery.
No. 1 Shaft.	18		103	52	lbs. 20½	120	2·09	3	6·3	1·18	6·6
Galleries of Ditto.	For time.	For materials									
	11¼	18	122	41	lbs 9 oz 12	81½	1·01	2¼	3·8	0·5	5
No. 2 Shaft.	21		102	52	lbs 26 oz 13	141	2·47	2½	825	1·2	6·7
Galleries of Ditto.	For time	For materials						worked without blasting			
	9	15	87	2	lbs 0 oz 8	4	1·24				
No. 3 Shaft.	9½		91	46	lbs 13 oz 4	100	1·25	4½	4.5	1·4	10
Galleries of Ditto.	For time	For materials									
	11	30	88	60	lbs 18 oz 15	132	1·5	2	5	0·63	4·4

It will be observed that the galleries branching off from No. 2 shaft were worked without blasting: blasts were tried, but it was found that the explosion produced little or no effect, from the gas escaping into the joints, and the work was therefore carried on by wedges and crowbars. The masonry in this pier consisted of very small stones.

Conclusions.—It may be deduced from these results—1. That shafts in this description of masonry cannot be sunk at a rate exceeding 2 to 2½ inches per hour, and that galleries proceed still more slowly, viz., at from 1 to 1½ inches per hour. 2. That shafts require on an average 3 blasts of from 6 to 8 ozs. of powder (or 1¼ lbs. of powder), and 7 feet of Bickford's fuze, per foot in length of excavation. 3. That galleries, where the masonry is formed of large stones, require 2 blasts of from 4 to 5 ozs. of powder (or ½lb. of powder) and 5 feet of Bickford's fuze, per foot in length of excavation.

Loading the Mines.—The powder boxes were filled in the gun-shed at Brompton Barracks, where the wires were also attached and coiled on the top of each box; slings of 2-inch rope were fitted to the boxes, and they were conveyed to Rochester Bridge in a waggon.

The smaller charges in the isolated pier were lowered into their places by hand, but the larger charges in the abutment, and pier supporting the arch, were lowered by means of a block and tackle attached to a triangle gyn, and were moved into their places on rollers.

The conducting wires of the Voltaic battery were led along the galleries in troughs, and up the shafts inside bamboos sawn down the middle, the cores being knocked out and the two halves being bound together again with spun yarn after the wires were inserted.

Tamping.—The tamping was performed with Medway clay and the stones and debris excavated from the shafts.

The clay had to be brought to the isolated pier in a barge, which could only lie alongside as the tide was making, there being danger of her grounding on the pier or starlings when the tide was falling; and this made the operation more troublesome than it would otherwise have been.

Firing.—The arrangements for firing the charges were entrusted to Capt. Cumberland, R.E. The explosions were effected by means of a Voltaic Battery on Grove's principle, as modified by Captain Ward, R.E., and described by him in Paper xvii., Vol. IV., of the New Series of Professional Papers. Forty-eight pairs of plates, arranged two abreast in two continuous series of 24 each, were used for the explosion of the 6 charges in the isolated pier. A pair of conducting wires ⅛-inch in diameter led from the battery to the mouth of the shaft, a distance of about 110 yards. At this point the two smaller conducting wires from each charge were connected with the two main conducting wires, so that the electric fluid divided itself at the point of connection to each charge. A series of experiments had led to the belief that this was the most certain method of exploding the 6 charges simultaneously with the available power of battery; from some unexplained cause, however, only three out of the six charges were exploded. The arrangements for the simultaneous explosion of the two charges in the pier which supported the arch, and also of those in the abutment, were quite similar, except as regards the battery: in these two cases 36 cells only, connected in a continuous series, were used.

Results of the Explosions.

Isolated Pier.—The charges in the isolated pier were exploded on Tuesday 13th January, 1857. The water was 4 feet deep over the surface of the pier when the

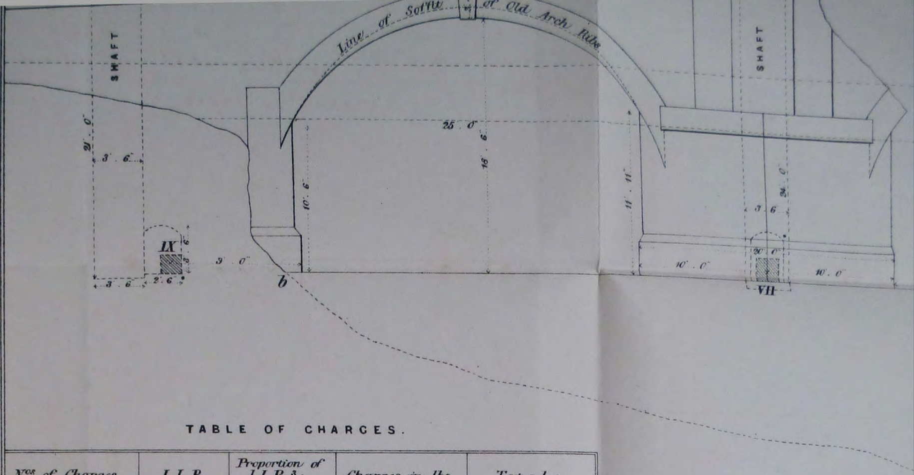
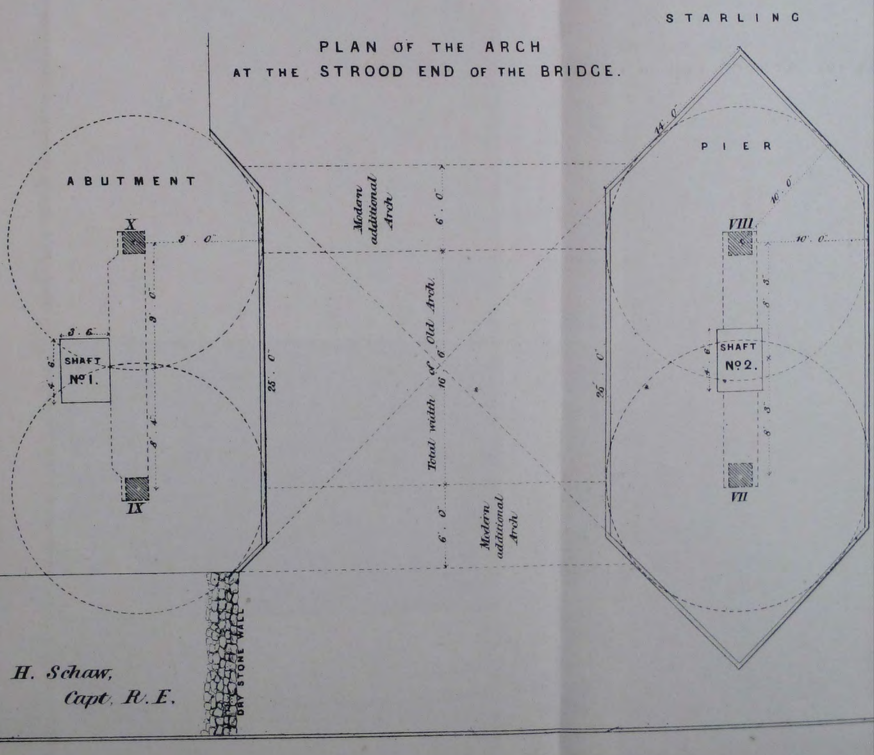


TABLE OF CHARGES.

Nos. of Charges.	L.L.R.	Proportion of L.L.R.³	Charges in lbs.	Totals.
I. II. III. IV.	7'. 6"	$\frac{3}{20}$	60	× 4 — 240
V. VI.	6'. 0"	$\frac{3}{20}$	30	× 2 — 60
VII. VIII.	10'. 0"	$\frac{1}{4}$	260	× 2 — 520
IX. X.	9'. 0"	$\frac{1}{5}$	150	× 2 — 300
				Total 1120 lbs

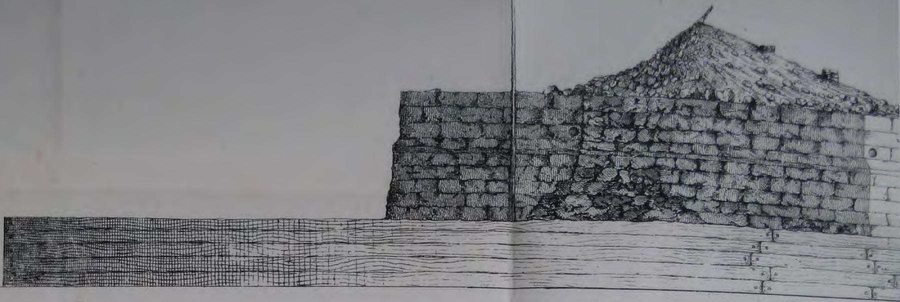
SCALE OF FEET $\frac{1}{120}$.

PLAN OF THE ARCH
AT THE STROOD END OF THE BRIDGE.



H. Schaw,
Capt. R.E.

FIG. 2.



ELEVATION OF THE EAST SIDE OF THE ISOLATED

AFTER THE EXPLOSION.

Scale of Feet.

10 5 0 10 20

N.B. Figs 1 & 2 were drawn by Lieut.s A. Durnford & M. Lamber

FIG. 3.

VIEW SHEWING THE EFFECT OF THE EXPLO

FROM A PHOTOGRAPH TAKEN FROM NEAR THE NEW BRIDGE BY SERGEANT W

charges were fired; but although the brickwork had been broken down to that level beforehand, the tide being slacker than was expected, only so much water flowed in as to cover the tamping to a depth of 1 foot. This placed the tamping of the shaft in an unfair condition, and it had the appearance of being slightly disturbed by the explosion of No. V.

Charges Nos. III, IV and VI did not explode.

Nos. I, II and V exploded simultaneously, shattering the up-stream end of the pier completely, and shaking the masonry right through to the cutwater at the down-stream end, so that the whole mass could be removed by the crowbar and pickaxe, without more blasting. The cutwater at the up-stream end was thrown forward about 9 inches, as shown by the dotted lines AB, BC in Fig. 2, and the demolition of this end of the pier was as perfect as possible, none of the stones being thrown over the edge of the starling, whilst the whole mass was thoroughly dislocated and broken up.

It is worthy of remark, however, that the effect of these charges did not extend more than 1 foot downwards, the stone landings, resting on the heads of the piles, being neither disturbed nor cracked. The results are shewn in Fig. 1 & 2, Pl. 2.

Arch.—On Thursday the 15th the mines in the arch, pier, and abutment were successively exploded. The 21 holes in the keystones of the arch were loaded by Sergeant Stacey and four men in an hour, 3 feet of Bickford's fuze being attached to each blast-hole. Two or three fuzes were tied together where practicable, so as to bring them all to 12 foci, one man with a port-fire being posted at each focus of ignition. Fascines and hurdles were laid over the blasts, and a rope-mantlet was hung over each side of the arch to prevent pieces from flying about.

The fuzes were lighted at the word "fire," and the explosions were nearly simultaneous, but the result was not satisfactory, as although all the key-stones were split and broken, only three were absolutely blown out, and the arch remained entire. This experiment did not admit of full charges being used, much less surcharges, for fear of endangering the spectators or neighbouring property.

Pier.—Immediately after the blasts had been fired, the connections were made with the wires from the charges in the pier, which were exploded simultaneously by the Voltaic Battery, and produced a complete, but not violent, demolition.

Abutment.—As soon as the other explosions were effected the wires from the charges in the abutment were connected with the Voltaic Battery, and they also were simultaneously exploded with a perfectly satisfactory result. See Fig. 3. Pl. 2.

No stones were projected by either of these explosions, and the whole mass of the abutment, arch, and pier was thrown down and remained on the starling, with the exception of a few stones from the pier, which fell into the river. The charges in the abutment and pier of the arch were 9 feet below the level of the surface of the water at the time of explosion. The water appeared to have only had the effect of causing the mass of masonry to be lifted upwards more than it would have been had there been no water around it. It may also, in some measure have kept the mass together and prevented the dispersion of the stones; but the powder appeared to have its full effect on the masonry, and to produce a demolition differing in no way from that which probably would have resulted had the charges been exploded at low water.

(Signed) H. SANDHAM,
Colonel, Royal Engineers, Director.

H. SCHAW, Captain, Royal Engineers.

It is intended to publish the Reports on subsequent Operations at Rochester Bridge in the next volume.—ED.

PAPER II.

Report on the Ceylon Government Railway Survey,

BY

CAPTAIN W. S. MOORSOM, Chief Engineer,

Accompanied by Notes on the Mode of Executing the Survey, by LIEUT. FESTING, Royal Engineers, Secretary to the Expedition.

REPORT.

To His Excellency Sir Henry George Ward, Governor of Ceylon, etc., etc., etc.

Kadoganawa, Ceylon, 12th May, 1857.

Sir Henry,

On the 24th of December last, I concluded the arrangement by which, under instructions from Mr. Secretary Labouchere, Her Majesty's Principal Secretary of State for the Colonies, acting on behalf of the Government of Ceylon, I undertook to proceed to that Island, for the purpose of determining certain questions which had there arisen, relative to the establishment of Railway communication. Mr. Labouchere's instructions, received by me shortly after the above date, and with which you are acquainted in detail, contemplated that, in compliance with certain "articles of two Agreements, entered into between the Ceylon Government and the Ceylon Railway Company, I should prepare and submit in Ceylon, to the Governor, with a Report, Plans, and Sections, together with estimates of cost in construction and working, and of returns from traffic, for the most eligible line or lines connecting Colombo and Kandy, including a due consideration of the line already surveyed by Mr. Drane."

On the 4th of January, the first division of my Surveyors left England On the 20th of January, a second division followed; and on the 4th of February, I sailed with the last portion of the expedition. On my arrival, I found that Mr. Atkinson, a Railway Engineer of twenty years' experience, who acted for me as principal Surveyor in charge, had actively fulfilled the instructions I had given him; and by means of the measurements and other observations then made, as well as by those subsequently taken by myself or under my immediate direction, I was enabled, without loss of time, to appreciate the levels and connecting features of this remarkable country.

The hill country of Ceylon, in which Kandy is situated, rising as a mass not less than 1,500 feet above the sea level, is encircled on its west and northern sides by mountains, of which none of the passes on those sides are less than from 1,500 to 2,400 feet above the sea. The intermediate ranges vary from upwards of 3,000 to upwards of 6,000 feet, rising in peaks to more than 7,000, and in one case, to more than 8,300 feet above the sea. The length and breadth of this singular elevated tract may be considered as about 60 miles each way.

The low country, from which this elevated district rises, does not attain more than 400 feet above the sea level, until the bases of the hills are closely approached; but this low country, also, is intersected with ranges of hills, partially isolated from their massive companions, and is dotted with hillocks almost down to the sea shore; so that while we may say that a general level, hardly exceeding 200 feet above the sea, characterizes some 30 miles from the shore, going inland from the neighbourhood of Colombo eastwards—beyond this distance, the inferior ranges, rising from this base in ridges varying in altitude from 500 to about 1,300 feet above the sea level, still render the next 20 miles more inland, practically a mountainous country. After 50 miles from the coast, there is no escape from the mountains : any Railway or Turnpike road (of which latter there are four) approaching Kandy from Colombo, or from the north, *must* encounter them : the question of how to do so becomes a perfect engineering problem ; and all other considerations of traffic or future railway policy must give way here to the physical features which Nature has imposed.

I must here premise that in quoting names of places I shall spell them as spelt on General Fraser's Map of the Island,* revised by Major Skinner, the present Civil Engineer and Commissioner of Roads in the Island. I know of no other method by which identity can be so well established.†

First, then, approaching the hill country from Colombo by the most southerly Pass of Ambegommowa, a Line may be laid down for a Railway, making the distance between Colombo and Kandy about 79 miles, and the ruling gradient one in 60, with the addition of a Tunnel, and an inclined plane of about one in 20, to ascend from the basin of the Kalany river to the basin of the Mahavilla near Genegatheina Pass, which is more than 2,100 feet above sea-level. This Line would have no part in common with the others about to be named, after leaving the first three miles out of Colombo, which three miles, as far as the crossing of the Kalany river, would be common to all the Lines I have contemplated The other Lines about to be named, have all a common course towards Ambepusse (about 35 miles from Colombo,) which course is ruled by the Ambanpettia range of hills striking for miles directly across the Colombo and Kandy road to a height of 1,300 feet, and the lowest Passes of which rise to 700 feet above the sea level, while the general level of the country around Ambepusse is only 2,500 feet. This range cannot be crossed with locomotive gradients of ordinary character, and can only be turned by taking the vale of the Maha Oya (river.)

2ndly.—Starting from Ambepusse towards the Amboolwawa Pass, which is the next most southerly from Ambegommowa, the total length of line for a Railway from Colombo to Kandy by this route would be about 82 miles, and the ruling gradient one in 50, obtained only by incurring an expensive Tunnel through the Pass, which is about 2,400 feet above the sea-level.

3rdly.—Again starting from Ambepusse towards the next most southerly Pass, we may ascend the Vales of the Maha, the Hingoola, and the Gadadesse Oyas (rivers) to the Parnepettia Pass, with a total length of Railway line from Colombo to Kandy of 79 miles, and a ruling gradient of one in 60, with a short Tunnel. The summit level of the ground at this Pass is 1,780 feet above the sea level.

4thly.—Again starting from Ambepusse up the Vale of the Maha Oya, and diverging thence under the base of the Mountain called Allagalle, and circling round its northern ranges, a Line may be obtained, the total length of which, from Colombo to Kandy, would be about 79 miles, and the ruling gradient one in 50, with a summit level of 1,770 feet above the sea-level.

The Passes of Kadooganawa and Ballany, which come next in order from the south, are too steep to be ascended by locomotive grades ordinarily so called.

We now come to the Northern lines, and of these,

5thly.—Starting from near Ambepusse, and running within two miles of Kornegalle, the next most southerly Pass of Gallegedera (the Turnpike road near the spot is only marked by the name "Madewellatenne" on General Fraser's Map) may be surmounted by a Line, the total length of which from Colombo to Kandy would be about 83 miles and the ruling gradient one in 45, with a summit level of the ground about 1,800 feet above sea-level.

6thly.—Taking the same route as far as Kornegalle, and thence by the Vale of the Ibbagamma to the Yattewatte Pass, near Ambokka, and up the Vale of the

* Published by Arrowsmith, Soho Square, London. † See accompanying Sketch.

Yatlewera Oya to the Pittiagedra Pass, a Line may be obtained, the total length of which, from Colombo to Kandy, would be 95 miles, and the ruling gradients, repeated frequently, but only for moderate lengths, one in 60. There would be two summits on this Line, at Yattewatte, and at Pittiagedra, the former upwards of 1,600, the latter rather more than 1,500 feet above sea-level.

These are all the Passes that have been either pointed out to me by the sedulous care of parties locally interested in the course of the Line, or which I have seen to be worthy of examination while roaming for the purpose amid the ranges of this truly magnificent country. It is remarkable that these Passes do not vary so materially in their absolute level above the sea, as in the respective modes by which they must be approached for Railway locomotion, having, at the same time, due regard to the expense of construction and of working on each Line. The most southerly Passes are the highest, and the most northerly are the lowest, viewed merely as matter of abstract level.

We must now consider the relations of these routes to traffic.

The route No. 1 by Ambegommowa is represented as to its traffic by Turnpike tolls to the extent of £37,300 per annum, and by a Boat traffic to the extent of £6,000 per annum, giving a total of £43,300 per annum, over 79 miles of Railway to be made, or about £548 per mile. But if a Railway were made in this direction, no doubt a large trade would come to the Kandy and Gampola Stations, and the total would probably amount to about £1,400 per mile per annum.

The route No. 2 by Amboolwawa, and the route No. 3 by Parnepettia, are represented, each by about the same amount of traffic; for while the Amboolwawa route would gain some of the Boolatgamme traffic which might be wholly lost to the Parnepettia route, the latter would gain some traffic towards Kirimittia, which the former would not take, except for a portion of its length. Thus balanced, each of these routes would be represented by a traffic of about £130,500 per annum, as evidenced by the Turnpike tolls, or at the rate of £1,591 per mile per annum, for No. 2 and of £1,652 per mile per annum for No. 3.

The route No. 4 by Allagalle would be represented by a smaller traffic than No. 3, because it would lose some of the Dollosbage and adjoining traffic, and would gain no adequate balance on the Tumpanne side of the country; it would be represented (in comparison with the other routes) by a traffic not exceeding £1,600 per mile per annum.

The two Northern lines are at present represented in their traffic by the Turnpike tolls on the Kornegalle and Kandy road, increased by those on the Kandy and Trincomalee road, and by those taken on the roads which converge on Kandy from the direction of Hoonisgirikanda. To these must be added such portions of the Kandy and Colombo road traffic, as would be attracted by the railway Stations of Kandy and Ambepusse.

These items, in the aggregate, would probably amount to about £101,760 per ann. for the route No. 6, by Pittiagedra, and to about 10 per cent. less for the route No 5, by Gallegedera; the amount being taken, in each case, from the same data as those which give the above comparative results on the other routes. Thus, the route No. 5, by Gallegedera, would be represented in comparison by a traffic of about £1,103 per mile per annum; and the route No. 6, by Pittiagedra, could be similarly represented by a traffic of about £1,071 per mile per annum.

We have next to consider the comparative costs of these routes; and for this purpose of comparison, I introduce only the items of cost which lie under the heads of Land and Property, construction of all Works and Stations, and supply of Working Stock. The cost of management and engineering, during construction, is excluded in all the cases, as being fairly presumable to be much the same whatever route may be taken.

Thus premised, I find the route No. 1 would cost £800,150.
the route No. 2 would cost £776,175.
the route No. 3 would cost £706,557.
the route No. 4 would cost £736,950.
the route No. 5 would cost £752,025.
and the route No. 6 would cost £953,500.

To these sums respectively, we may add about £150,000 for management during construction, and for unforeseen contingencies.

Taking into consideration all the foregoing facts, and still viewing each route comparatively and not absolutely, I come to the following conclusions:—

The route No. 1, by Ambegommowa, involves objections as to its inclined plane and expense, together with a paucity of general accommodation, which are not counterbalanced by any sufficient advantages to the Public. It may therefore be thrown out of future consideration.

The route No. 2, by Amboolwawa, is convenient for general accommodation, but involves a cost at the rate of nearly £11,300 per mile, with a gross corresponding traffic which would yield at the rate of about 14 per cent. per annum on the cost of the Line.

The route No. 3, by Parnepettia, is, at the least, equally convenient with any of the others for general accommodation, and involves a cost at the rate of £10,800 per mile with a gross traffic at the rate of 15 per cent. per annum upon the cost of the Line.

The route No. 4, by Allagalle, gives a similar item of cost to No. 3, with a resultant traffic at the rate of 14 per cent. on that cost, and less general accommodation than any of the other Lines except that by Ambegommowa. It does not therefore seem to have claims for further consideration.

The route No. 5, by Gallegedera, accommodates Kornegalle, but fails in accommodating the populous districts which lie on or near the Turnpike road between Ambepusse and Peradenia. It involves a cost of nearly £10,900 per mile, with a corresponding gross traffic of £1,103 per mile, or at the rate of nearly 10 per cent. per annum on the cost of the Line, and it has besides the disadvantage of comparatively bad gradients. This route shows no advantage sufficient to counterbalance the above comparative defects, and may therefore be thrown out of further consideration.

The route No. 6, by Pittiagedra and Matella, accommodates a northern and north-eastern district, which give it peculiar claims for consideration.

Under my instructions, however, from the Secretary of State, it must be placed in the same scale of comparison with the other routes above enumerated; and thus viewed it gives the above stated north and north-eastern accommodation at a loss of accommodation to all the traffic converging upon the Colombo road from Kaigalle on the west, as far as Peradenia on the east, including Allagalle, Kadooganawa, Gampola and Dollosbage. Its cost would be about £10,600 per mile, and its gross traffic less than £1,100 per mile, or at the rate of about 10 per cent. per annum on the cost of the Line.

Viewed in these general positions, it is evident that the routes No. 2 by Amboolwawa, and No. 3 by Parnepettia, have prominent features of accommodation which entitle them to nearly equal favor: but the route No. 2 is less remunerative than that numbered 3 by Parnepettia, and it has besides, the engineering disadvantage that the trains upon it would require engines of a power which may be familiarly represented by 56 horses as compared with 48 horses, which the same trains, working at the same speeds, would require on the Parnepettia Line. I am of opinion, therefore, that the Parnepettia Line is preferable to that by Amboolwawa.

There remains for consideration, comparatively, the route by Pittiagedra, No 6, with that by Parnepettia, No. 3. The main considerations which have been urged on me, locally, in favour of a Line from Colombo to Kandy *via* Matella and Pittiagedra, are the extremely productive character of the Coffee Estates in the Districts through which such Line would pass, and the connections which would be thereby advanced with the Northern and Eastern Provinces of the Island. Taking first the productive powers of the Districts in question, and supposing their produce to be delivered at Railway Stations on the respective routes, I find from a comparison of Returns, with which the Surveyor General, the Government Agents, the Chairman of the Planters' Association, and the Secretary of the same Association, have supplied me, that the number of acres which would be better accommodated by a Matella and Pittiagedra Line, is represented according to the Government Map, by 39,800 acres, and in the Chairman's Return by 22,900 acres; and the produce which would be thus accommodated is about 114,000 nett cwts. of Coffee. The Chairman has subsequently written to me that this figure should be 141,000 cwts.; but upon a revision, I differ from him in applying to the respective stations the figures given in his own Returns. On the other hand, the number of acres which would be better accommodated by a Parnepettia Line, is represented on the Government Map by 132,400 acres, and on the Chairman's Return by 45,000 acres; and the produce which would be so accommodated, is, by the Government Return, about 201,000 nett cwts of Coffee, or by the Chairman's Return, about 187,000 nett cwts. While these figures, taken from different Returns, differ as to the number of acres, and in the last instance as to produce, it will be observed that they agree in shewing that the *relative* accommodation as regards Coffee, is nearly in the proportion of two to one on a Line by Parnepettia, as contrasted with a line (in each case from Colombo to Kandy) *via* Matella. We are therefore left with the consideration, whether any large traffic, either existing, or certain, or likely to exist, northwards and eastwards from Kandy, would justify the turning our backs upon the largely producing districts west and south of Kandy. Now, turning to the Tolls received (as rent by Government) from the Toll-bars and Ferries on the northern roads out of Kandy, including those to Hoonisgiri, to Matella, and to Kornegalle, I find the gross produce of these Tolls—as sold for 1857 on the Matella and Hoonisgiri Roads—was at the rate of £137 16s. per mile of road; and on the Kornegalle and Kandy Road, including the Allowe Ferry, at the rate of £21 16s. per mile of road; giving a mean of £67 15s. per mile of the whole of these roads.

During the same period the Tolls of the Colombo and Kandy Road between Peradenia and Kaigalle—short of any northern traffic—have been sold at the rate of £383 per mile of road.

Deducting the first mentioned rate of Toll as being derived from goods susceptible of northern and eastern carriage—and thus taking an amount per mile evidently larger than is due from the last named rate, or in other words giving credit to the Matella district for providing £137 per mile towards the Tolls on the Colombo and Kandy Road between Peradenia and Kaigalle, and deducting this to the credit of Matella, we still have a preponderating interest of traffic represented by Tolls at the rate of £246 per mile, to convince us that there is no existing large traffic north and east of Kandy, sufficient to induce a circuitous course in that direction towards Colombo. Still the question remains, is there any large traffic certain, or likely to exist, northwards and eastwards of Kandy, in the event of Railway accommodation being afforded in a direction which may combine the traffic of those points? In the present state of the Island and its internal relations, this is very difficult to answer in the abstract. There is a large connection (about 87,000 persons in 1856) with the north in labourers (coolies), who come and go as regularly as the men of Connaught and other parts of Ireland used to visit England. Cattle also are driven in tolerably large numbers from the same direction—(about 1,200 horses, and nearly 58,000 sheep and goats passed one of the

Toll bars in 1856). Persons officially connected with the Eastern Province, however, admit that there is "scarcely any traffic between Kandy and Trincomalee," and state that whatever does exist is confined to fish carried upwards without a return load. They attribute this to the want of good roads, which, if made, "might divert a large portion of the traffic now on the Kandy and Colombo Road to Trincomalee," as being a better harbour for shipments than Colombo. I have failed to discover any tangible ground for expecting a large,—that is to say, a remunerative Railway traffic, in the directions quoted; and I am of opinion, that experiments, upon grounds of future speculation, without any present basis, ought not to be made with British capital, raised upon a guaranteed interest, for which the people of Ceylon may be taxed. Some years hence, there may be sufficient ground for probable remuneration, to connect the interior of the Island with Trincomalee, which is certainly the finest Port, and possesses the only Dock Yard of the Island; but the country must be opened, and commercial connection rendered apparent between that Port and other countries, before the expense of Railway accommodation can, with reason, be incurred in that direction. There is an existing and large traffic between Colombo and Kandy, certain to remunerate the adventure of a Railway Company, if that Company conduct its operations with prudence and economy, and if it be met by the Government with experience and liberality, as to the control which the Government has obtained the right to exercise.

On this ground, and subject to these conditions, I recommend the route No. 3 from Colombo to Kandy, *via* Parnepettia, as being that which combines the greatest amount of public accommodation with that which affords the most remunerative prospect; and to the details of this route I now address myself.

Commencing at Colombo, at the Canal or head of lake water near the back of the Kutcherry, a Goods Depot should here be formed, for the receipt and delivery of all goods connected with the numerous Mills and Stores on the borders of the Lake, as well as the general goods for Colombo city. And from the Custom House Quay, a line of rails carried along the new road, and through the arch of the Leyden Bastion, (which by the timely foresight of Col. Hope, R.E., has been constructed in a manner suitable for this purpose,) may be further laid along the Bankshall Street, to join the before-mentioned line of rails from the Canal on the sea-shore road; and when thus united, the line will lead to the open space in front of the native Church called St. Thomas's, at the very outlet of the business carried on in the Pettah (suburb) of Colombo. On this space should be placed the terminal Passenger station. The site is partly Government property.

The Locomotive Line, commencing at this station, will run at the back of the Mutwall Road, behind the Bishop's residence, and will cross the Kalany River a quarter of a mile below the Bridge of Boats at an elevation sufficient to admit the highest loaded boats at all times of navigation. A station should be placed at the crossing of the Negombo Road, 2¼ miles from the terminus in Colombo. From this point, the Railway Line proceeds in an easterly direction, nearly parallel to the Kandy Road. It crosses the road from Mahara to Negombo at a distance of 1½ mile from Mahara, and at this point should be a station 8 miles from Colombo. At 15½ miles from Colombo, the Railway Line crosses the road from Heneretgodde to Negombo, at a distance of half a mile from Heneretgodde: here also should be a station. At 21¾ miles from Colombo, the Railway Line crosses the Veangodde and Negombo Road, at a distance of 2½ miles from Veangodde: and here also should be a station. These cross roads are all well formed, and will bring traffic to and from the railway. At 30½ miles from Colombo, the Railway Line crosses the road from Passyale to Girioole Ferry, near the 5th mile post from Passyale: and here a small station should be placed. At 37¾ miles from Colombo, the Railway Line crosses the Ambepusse and Kornegalle

Road, near the 39th mile stone on that road. Here should be a first-class station for traffic to and from the north-east, and a bridge, in lieu of the Allowe Ferry, would much facilitate access from the Kornegalle side of the country, and would present but little difficulty in execution. From this station, the railway will ascend the left or south bank of the Maha Oya, crossing about 5 miles onwards the foot-road from Kaigalle to the Polegahawelle Ferry (where, probably, hereafter, a small station may be usefully placed), and will continue along that bank to a point about 2½ miles below Gordon's Bridge, where it will cross the Maha to its north-eastern bank, and will continue ascending the north-eastern bank of the Hingoola, till it arrives at Gordon's Bridge, 59½ miles from Colombo. Here long sidings and a long approach-road, from the Turnpike Road to the station, will be desirable for waiting waggons, as this station will be the breathing place for the Locomotives, before ascending the Ghauts, or passes into the hill country of the Kandyan Province. From Gordon's Bridge the Line will cross the Hingoola and the Turnpike Road, and will take the left or south bank of the Gadadessa Oya for four miles, and then cross to the north bank of the same stream near Mr. Lambe's stores. At this point should be a station for several Estates, the traffic of which will converge thither. After leaving this station the Railway Line will keep the right bank of the Gadadessa, until the rising gradient enables it to turn over the high land which separates the Gadadessa from the upper Hingoola, into the valley of the latter, up which it is carried to Parnepettia (Craig's) Bridge. Here another station will be required for the accommodation of many Estates in the neighbourhood of Amboolwawa. Continuing up a northerly banch of the Hingoola, the Railway attains its summit level of 1690 feet above the sea, at the east end of a Tunnel 750 yards in length, at about a mile and a half from Craig's Bridge, in the valley of the Illukwatte water, near the Hindu Temple of Wallapolla. The Line then descends to the Kandy and Colombo Road, at the 64th mile stone. Here should be a station for the accommodation of the Alłagalle Estates, and for the populous neighbourhood of Kadooganawa. Crossing the Kandy road at this point, the Railway descends along the north bank of the Nana Oya, crosses the Kandy Road again at the Nana Oya Bridge, and keeps the vale of the Nana to its junction with the Mahavilla Ganga. It crosses the Gampola road at the Nana Bridge on that road, one mile south of Peradenia, and seven miles north of Gampola. Here should be a station for the traffic which converges from all sides on Gampola. The Mahavilla is then crossed at an elevation of about 40 feet above its bed, and the Railway Line proceeds in a nearly straight direction skirting the south of the race course, and thence parallel with and on the south side of the Colombo and Kandy Road, to the entrance of Kandy,—terminating in the open plot of ground, which is the property of Government, opposite the Post Office; and at a level which renders it capable of extension onwards hereafter, towards the Kattugastotte or Allutgantotte Ferries.

It must be clearly understood that while this Line is the general Line of Railway which I recommend agreeably with my instructions, there are some places where the Line may be amended in detail under a license similar to that which Parliament allows to Railway Companies in England. The license (which is there confined to 100 yards on either side) may be extended in this case to half a mile on either side of the Line throughout the country districts, and to 100 yards on either side in the town plots. I have preferred leaving the Line open to these amendments, rather than to make them myself, because they are tolerably obvious to any experienced eye, when the plan and sections are compared with the ground, and they may be easily made hereafter when the Line is finally set out;—and if amended now, I should only lower the estimate, whereas, as I know the amendments will make a saving on one hand, this saving will go to balance any excess on the other hand that may arise from matters which, in a large and complicated series of works, can never be altogether provided against beforehand.

The levels of the Line may be briefly described as undulating for the first 48 miles out of Colombo, and in no instance exceeding one in 132 throughout that length. This gradient is found on some of the British Lines of largest traffic, for instance on that from London to Woolwich, Chatham and Dover, and on the great Irish Line from Dublin to Cork and Limerick. After 50 miles from Colombo the rapid rise of the basin of the Maha Oya is met by a gradient of 1 in 70, steepening to 1 in 66, and running up to Gordon's Bridge station (where every train must stop), with more than two miles rising 1 in 60. This portion of the Line is similar to the Great Western and South Wales Line through the Stroud Valley in Gloucestershire, where the gradients run up from 1 in 70 to 1 in 60, and are passed daily at speed by express trains both up and down. From Gordon's Bridge to the summit, a distance of nearly ten miles and a half, the Line is a continued ascent of 1 in 60. It is here similar to the Cornish Lines which I laid out in 1843 to 1845, and which Mr. Brunel is now completing for all the Cornish traffic between Plymouth, Truro, Falmouth, and Penzance. The gradients of these Lines ascend and descend the slopes of the steep granitic and grauwacke hills of Cornwall at long inclinations of 1 in 60, and will no doubt be worked with Passenger Trains at a speed of 25 miles per hour, and with goods trains at from 12 to 15 miles per hour. From the summit at Wallapolla the Line descends with easier gradients to the Mahavilla and rises thence to Kandy, nowhere exceeding an inclination of 1 in 132.

The more important works to be constructed on this Railway are but few: the line has been laid out with as much care towards construction as the determination of a general Line will admit. Commencing at Colombo end, the Bridge over the Kalany is a work of ordinary magnitude, on a bottom of firm sand overlying rock, as far as I have been able to judge. It is a work similar to that over the River Severn, in Gloucestershire, which I laid out in 1845, and which Mr. W. Cubitt, the well-known Contractor, offered to construct, in timber, for £1,800. I should propose a different construction in iron, for the Kalany Bridge, and have estimated accordingly. From this point, there is no work worth mentioning, till we come to the Maha Oya, at the 57th mile. Here, an ordinary Bridge, about five feet above the bed of the river, (which will be lowered) and with about 150 feet width of water-way will be required. There is stone fit for building about the spot, and also on the foundations.

At Gordon's Bridge is one of the most important works on the Line,—a Viaduct to cover the river and roadway, and at a height of 107 feet above the latter. There is good stone for this on the spot, and the work is almost the same in height and length with one I lately executed in Ireland, and of which the total cost, for double way, was £9,300. The Hingoola Viaduct, at Gordon's Bridge, being for single way, ought to cost less. There no works worth mentioning upon the ascent of the Ghauts to the hill country, unless we except some heavy work in the Gadadessa which is susceptible of amendment.

The line is scraped, as it were, along the sides of the hills, like the Turnpike Roads, whose constructors deserve great credit for the skill with which they have thus carried them up Passes apparently so formidable at first sight. There are some formidable looking cuttings on the upper Gadadessa, but the material is excellent. The Wallapolla Tunnel begins at both ends in clay, but will soon run into indurated sandstone, formed by the disintegrated quartz and mica, which are evident in the numerous natural sections around. No doubt, blocks of solid stone will be met with in it, and it must be carefully drained; but with these points of foresight provided for, it will be found to be a very ordinary work. It might be dispensed with altogether, by a deviation of the Line, if the name of a Tunnel be distasteful; but I prefer it to open cutting in the position it will be in, on account of the comparative safety from rushes of water. The Nana Oya will be crossed thrice, and diverted in another place, but the Bridge will be insignificant. The Mahavilla Bridge will require about 200 feet for water-way, and will, probably, be the most expensive Viaduct next to that of the Hingoola. Stone is to be had on the western bank, and for the arch, I am inclined to recommend an iron lattice design, with a single span. From this spot into Kandy, there is no work worth naming. The terminus is on the level of two roads, thus giving a double frontage for Goods. as well as for Passengers; and there is a mound of earth at the spot, to afford excellent material for the station yards and platforms, so as to serve a large goods trade, which will, no doubt, be done here.

Continuing with details of the Line, I must next mention the principal curves. These are easy, until we get into the tortuous basin of the Maha Oya, beyond the 50th mile. Subsequently, the Line is laid out with curves of 12, and sometimes of 10 chains' radius, in situations where deep cutting or lofty embankment is to be avoided by such curvature. These curves are of like radius with those at Bristol on the Exeter Line, and at Newton on the Birmingham and Liverpool Line; on the former of which I frequently pass in the Express Train, at 35 miles per hour. The only curves of small radius are at Craig's Bridge Station, and at Gadadessa Station, each of about 8 chains' radius, which is about the same as those at Southampton on the South Western Line, and at Birmingham on the Midland Line, over the latter of which is daily passed all the trade of the Midland Railway, between Leeds, Derby, and Bristol.

I have now to state the material to be found on the Line, and the mode I recommend for executing the works.

First then as to the material. The almost universal material of the district through which the Railway will pass the whole way from Colombo to Kandy, is of a granitic basis – syenite, gneiss, hornblende, and granite, are found to compose the stones we pick up, and boulders and masses we frequently see around—but the disintegration of these bases is such as I have never witnessed elsewhere to the same extent. Universally the roads are cut—(and from 20 to 40 feet deep in many places) with the spade, or rather with that abominable instrument like a hoe called the "Mammotie." I have poked my stick repeatedly into a face of what I took to be granitic rock, but found it to be indurated sand. About 20 yards per mile on any given line of road that I have traversed (and in the course of this survey I have traversed more than 800 miles) seems to be the average extent of solid rock to be met with in the shape of boulders and eruptive masses. Sometimes the run of stones and rock will continue for two or three hundred yards, but of this I do not remember more than two instances. Mr. Evatt, the Assistant Commissioner of Roads, tells me that he finds he has to send long distances for a sufficient supply of hard road metal.

The roads are usually cut with a slope of a quarter to one—or vertical. There is clay (disintegrated felspar) to be found frequently, and many brick and tile yards are established along the roads: Kaolin clay is not unfrequently met with, and will hereafter probably become an article of transport.

Limestone is found in abundance in crystalline form in the Matella district and also at Peradenia. At Colombo coral is used for the purpose. I am informed by Major Skinner, the Civil Engineer of the Colony, and who knows the Island well, that lime stone is to be found on the banks of the Maha Oya, where the Railway Line passes, but I have not myself seen any there.

Timber is abundant for ordinary building purposes, and I am assured by the native Chiefs that they have on their estates along the Line of Railway more than can be required; but I do not believe that this will be found to be so. Although a good deal of timber may be had - and probably quite enough for temporary sleepers, for fencing and for the station buildings, and such Bridges as it might be desirable to use wood upon (and these would be very few)—still I think the permanent sleepers must, in the main, be imported, or else if cut in the country and carried to the Line, they will cost as much as if imported. I have a list of eleven woods of Ceylon which seem well fitted for sleepers, and of 24 woods from the opposite coast of Malabar which have been found to be so. Besides these, several other woods are well known for dry building. For fencing I should prefer the "Indaroo;" but there are sundry other quick growing woods—"Sooria," "Prickly Pear," "Cactus," and "Aloe," — which, if properly treated, will make excellent fencing at about one third of the prices which we pay in England. Ditching will form the Railway fence for many miles.

The entire Line is bestrewed with ballast of the best description, except only where it passes over the paddy (rice) fields. The maintenance of such a line ought to be cheap, if the drainage is carefully and skilfully made, and attended to afterwards. In forming the Railway through paddy fields, special care should be given to the water levels, and penstocks should be provided wherever necessary for the irrigation.

The best mode of executing the Ceylon Railway is a matter of the utmost importance to be well considered, and as a point involved in such consideration comes the question—How is labour to be provided for this work?—A question viewed with alarm by the Planters, and in which view, I confess, I concurred to some extent until I had more fully studied the question. I am now persuaded that under such wise and cordial co-operation between the Railway Company and the Government as I have elsewhere stated to be indispensible to the success of the undertaking, not only may sufficient labour be provided for the Railway without draining labour from the Estates to any appreciable degree, but the Estates themselves may receive a surplusage of labourers from the Railway, just as in England I have found that during harvest time our numbers on the Railway diminished when we were not unduly pressing the works, and not paying time wages to our labourers on those works.

I think that the Railway Company should have a liberal discretionary permission accorded to them by the Government, to apply a portion of their funds to aid the contractors—by bringing from the several coasts of India where labour is abundant, and not from the Malabar coast only, such labour as by conference with the contractors may be deemed best suited for their purpose. The Company thus acting, not by way of interference with the contractor's labour, but as the medium through which the contractor's association (if I may so term it) may supply itself.

I do not mean by this suggestion to interfere with any operations of the proposed Coast Navigation Company for Coolie transport—if they become organized and are the medium of the necessary supply, all the better—but should they fail to act, I see no extraordinary difficulty in acting as above suggested, and indeed I have been obliged to act in a somewhat similar manner on a former occasion.

It will be seen by this suggestion that I do not approve of "large English Capitalists," or a "first rate English Contractor" undertaking this Railway. This would be simply, in other words to put £150,000 at least, (I write advisedly), into the pocket of some individual who would appear to deserve that bonus, because he would give timid shareholders and ignorant directors the assurance or guarantee that a fixed amount of expenditure would not be exceeded. But that guarantee would include, at the least, the above amount of bonus, and the Company and the Ceylon Government are alike interested to save this by organizing a judicious system of moderately sized contracts, suited to the means of those, who I happen to know, are ready both in Ceylon and in India, as well as in Great Britain, to give in tenders for the execution of portions of the works.

This naturally leads me to describe those works, and the mode in which I would suggest their being executed locally.

My estimate is for a Railway formed 18 feet wide, and with cuttings on the average sloping ½ to 1, and embankments sloping on the average 1½ to 1. For a mile at each station the Railway is to be formed 30 feet wide, and proper sidings in addition are estimated. Thus we have single track intermediate, and double way at stations. Land is estimated for 30 feet width throughout, and an Electric Telegraph is estimated with 3 wires.

Five classes of works may be recognized.

First, where large masses (small though they be compared with similar works in Great Britain) of earthwork, together with their accompanying culverts, must be executed with wagons and rails. This class comprises only a few cases, and in every case a road exists near the work, by which the contractor may bring his materials upon or very near to the spot, and the largest mass will not exceed 90,000 cubic yards.

Secondly, those earthworks where mere cutting down on one side and barrowing over to the other is to be done, or where very short runs, to be accomplished by the barrow alone, are necessary.

Thirdly, those Bridges or Viaducts, with or without their accompanying embankments, which may be let as a contract either together or separately.

Fourthly, the tunnel at the summit of the Line, which is an ordinary tunnel, accessible by cart roads, with brick-earth, fuel, and stone at hand, and therefore peculiarly open to any tenders from English Contractors, to compete with those more locally acquainted.

The fifth class of works are those which comprise the Permanent Way (rails and their bearings and fastenings), and the Working Stock. For the supply, in the first instance, of these articles, except timber bearings, the Railway Company must be dependent upon England; but as soon as the patterns are thus imported into the Island, local makers will be found to make, in a way better suited for this Country than can be done in England, all the wood-work of the carriages and other appurtenances of the working stock. I have seen specimens of the Island make, which lead me to believe that these items will form a new, or rather a greatly extended branch of local industry.

With regard to the mode of executing these several classes of works, it will be evident to those who know the Island that it is only the tunnel, and the larger masses of earthwork that will require any importation of Europeans, other than overlookers. Out of 79 miles of Railway to be formed, about 50 are either side-cutting or ditching, and the remainder alone will require wagons and rails for leading the excavated material to embankment. The hill country will require careful drainage on the tops of the slopes, and I have estimated for forty culverts per mile over this portion, so that the line, when thus properly formed, shall be kept dry, and safe from liability to sudden rushes of water, which rapidly destroy some of the minor roads in the Island. The Kandy and Colombo Road, where it enters the Passes, is as good a sample as I can point out of the mode of formation by which the Railway should be kept dry; and the hill road close to Kandy, called "Lady Horton's Drives," is a fair sample of what the Railway will be, when its cuttings are formed through the Hill Country. The only addition I can point out is, that a catch-drain should be led along the tops of the slopes of cuttings, in every situation where water can, by possibility, make a rush towards them; and these drains must be led right down the slope in steps, and under the Railway clear down the hill.

The Bridges and Viaducts will require nothing more than foresight, to provide the stone and brick in time for the earthworks. I think the larger spans will be best executed in iron ; and for the Kalany, I should recommend the piers to be iron cylinders, laid in the admirable manner first introduced by Mr. John Hughes, at Rochester Bridge, and now well known to the profession.

If the Railway Company will confide the laying out of their works and their contracts to an Engineer capable of organization, (rather a rare quality), and at the same time skilful in his technical application, and will abide by the principle I have here endeavoured to shadow forth, they will have an ample margin for executing their works and completing the Railway I have recommended, within the sum already stated, viz , £856,557. If, on the contrary, the Company neglect those precautions, they will increase their expenditure and diminish rateably their dividend, and the funds of the Island will proportionately suffer. The Company must organize an efficient and well paid staff of skilful Engineers, under a chief who can control, and keep in perfect and harmonious action, a force as large as a division of the British Army—say five or six thousand people, with all their appliances. The Railway Line must be subdivided into portions, comprising distinct and separate works, each portion being in the responsibility of an Engineer, who shall properly set out each work, and place it in the hands of a contractor, and control the contractor with vigilant supervision till the work is completed. The contracts must be simple, and clearly drawn up by the Chief Engineer, with sufficient detail to enable a contractor to see what he is required to produce, without tying him too much as to his mode of production. If this system is pursued, sufficient competition and labour will flow towards Ceylon from India as well as from Europe.

I have now to state the prices upon which I think the actual cost of the respective works (including overlooking, and all materials, except a certain quantity of rails stated below) may be calculated, and to which each contractor must add such profit as he thinks competition will admit, taking into account, on the other hand, any better or cheaper mode that he himself may devise for executing the works. In my total estimate, I think, I leave him fair margin for a profit of 20 per cent.

These costs are as follow :—

For clearing the jungle, at from 30s. to 50s. per acre.

For fencing on the ordinary Line, from 3d. to 4d. the lineal yard, single line of fence.

For fencing at stations, from 1s to 6s. the lineal yard, single line of fence.

For earthwork formed by side cutting or by ditching, from 4½d. to 6½d. per cubic yard, on the average.

For earthwork excavated and led beyond the above stated formation, for 1½d. to 3d. per cubic yard, (in addition to the side cutting or ditching price)—for every quarter of a mile so led, the use of a certain quantity of permanent rails being allowed to the Contractor.

For blasting runs of rock in the cuttings, an average price of 2s. 9d. per cubic yard.

For masonry in upright walls, from 5s. to 11s. per cubic yard.

For masonry in upright walls, dry laid, from 2s. 6d. to 3s. 6d. per cubic yard.

For brickwork in upright walls, from 13s. to 15s. 6d. per cubic yard.

For brickwork in arches, from 7s. to 17s. per cubic yard.

For ballast laid in place, an addition of 4d. per cubic yard (upon the price of earthwork, if previously paid as such beforehand), with the price for leads respectively, as above stated.

For rails and all other iron work the English market price of the metal, with 30s. per ton in addition for freight to Colombo, and an average price of 30s. more per ton for delivery from the ship to the Line.

For fitting permanent way, for the first thirty miles so fitted, double the English price, say 2s. per yard, and after that say the usual home price, with native fitters.

For timber at Colombo from 1s 6d. to 5s. per cubic foot, and in addition an average price of 9d. per cubic foot for delivery upon the Line.

For Station buildings, an average price of from 3d. to 6d per cubic foot of capacity of each building, taken from the outside dimensions; and without interior fittings.

For freight from Great Britain to Colombo an average of 30s. per ton for dead weight; but carriages or engines sent in bulk must be specially allowed for.

For carriage from Colombo inland a rate of 5d. per ton per mile, but an addition must be made to this, dependent upon local position, if the delivery is to be made away from the main or any good cross road.

For labour of excavators or ordinary labourers on the roads, from 6d. to 9d. per day.

For labour of masons, bricklayers, smiths or carpenters, from 1s. 2d. to 1s. 6d. per day.

For overlookers from 1s. 6d. to 2s. per day.

All tools for European workmen, or indeed, tools of any description, to be relied on, must be procured from England.

Upon the basis of these prices it will be found that the Railway works, as exhibited by the Plans and Sections appended to this Report, will not mount up to the sum total I have assigned for them, and it must be remembered that my estimate of £856,557 includes the purchase of land, the working stock and the cost of the accessory establishment during the execution of the works, which I think ought not to be pushed hastily, while, at the same time, vigilant care must be exercised by the Government, that no time be wasted.

I do not think it desirable to open any one portion of the Railway before the whole length is ready for traffic, – chiefly because the lower division of the Line near Henneregodde comprises works which will take as much time to execute as any works upon the upper divisions; and the cost of opening patches of Railway, (when the total length is under 100 miles), has seldom, if ever, been found to be answered by any corresponding profit. On the other hand, under the peculiar clauses of agreement with the Railway Company, as to opening the Railway in divisions consecutively, it is desirable that the Railway Company should not delay the opening of a portion of the Line beyond three years from its commencement; and I believe, that a satisfactory arrangement might be made, to open, at least as far as the foot of the Kadooganawa Pass within three years, if the opening of the whole Line be delayed beyond that period.

Taking into consideration that the same sum of £856,557 only is required for the trunk Line from Colombo to Kandy with its rolling stock, and that the agreement with the Railway Company contemplates the sum of £1,200,000 to be raised for the purpose of Railway accommodation, it may become a matter of further consideration, whether the balance may be assigned either wholly or in part to an extension of that trunk Line. Now upon a general review of the subject, it will appear that two districts, one to the north-east, the other to the south of Kandy, possess each at present a considerable traffic, and one which is yearly increasing. From the direction of Matella and Hoonisgirikanda, I have elsewhere stated that the Tolls give a rent of about £137 per mile per annum, and in the direction of Gampola, (I mean to the south east of that place and not including Peradenia) the Tolls produce about £107 per mile per annum. The latter direction has the advantage of an easy Line for the formation of a branch Railway as far as Gampola for a length of 7 miles, which would probably be executed for £50,000. A similar extension towards Hoonisgirikanda would be more costly per mile, because the direction must be taken from Kandy transverse to the river Manavilla, and an expensive Bridge must be incurred and an expensive tract of land through Kandy must be purchased. Seven miles in this direction, to the head of the Yatlewera Oya, would cost probably not less than £70,000, but the head of the Yatlewera is the key to a northern Line, for the future, and to the opening of an excellent road from the rich districts of Matella and Maturata,—and as the aggregate of these sums amounts to £120,000, still leaving a margin upon the contemplated capital, it may be well to consider how far a judicious expenditure in one or both of these directions may benefit the principal interests of the Island, and still produce a remunerative return sufficient to redeem, or at least to relieve, the guarantee. The earnings of the Matella Branch (based on the above receipts of tolls) would probably not exceed £7,000 per annum for the first two years, and the earnings of the Gampola Branch on a like basis would probably not exceed £4,200 per annum during a like period; but it must be considered, that in addition to this, the traffic of the main Line would receive a small increase per mile which it would fail to get, were these extensions not made. In point of time, it may be well to wait until at least the period when the contracts on the main trunk Line shall be nearly completed, or even till it has been practically shewn that the trunk will pay the guarantee, but it may also be well to have this part of the subject so previously considered and arranged, while there is ample time for the arrangement, that no frittering away of the surplus funds of the Company shall be allowed, either on ornament, or on ill-judged amendments of a plain and practical working Railway,—instead of applying those surplus funds in extending the working rail, where it shall accommodate the public and reap its own fruits in return for the accommodation, under equitable agreement with the Company as to the extended length of Railway, which would thus be made.

I must now finally state the grounds upon which I am of opinion that this Railway when completed, as I have above described, for nearly £857,000, will be remunerative to the Company apart from any guaranteed dividend.

Having before me the returns of Exports from, and Imports into the Port of Colombo; the returns of produce in the Kandian and Western (Colombo) Provinces; and the relative prices of articles, in those respective positions, I find that while the staple produce of districts which the Railway will connect is Coffee to go down and Grains to go up, still there are a number of other articles which may be enumerated under about forty different heads, which will be interchanged between the districts in question. I find further, that an article in Colombo differs in price from the same article at Kandy as much as from 25 to 100 per cent. at the same period. This applies to 17 articles of general and daily consumption, without taking into account any of the numerous minor articles which form items of Railway carriage. I find further, that between Kandy and Colombo, about 100,000 journeys of bullock carts (bandies) each conveying when loaded an average of from 12 to 15 cwt were made during the year 1856, and although I have carefully watched these bandies, which literally swarm on that Road, and cause the greatest conceivable nuisance to faster travellers by blocking up the way, I have not been able to discover more than three that I could positively say were empty. It is unreasonable to deny conviction that there must be a large goods traffic on the railway under these circumstances, and I estimate the amount which may be derived from these sources, if freights and stations on the railway are properly arranged, at nearly £85,000 per annum, the proportions being two thirds of the weights to go up and one third down. The passenger traffic is at present restricted to the daily mail coaches up and down, which charge 50s. between Kandy and Colombo for 72 miles, or at the rate of 8½d. per mile, but natives who are supposed to be so poor as to be unable to pay that rate of fare are taken at half price, or at upwards of 4d. per mile—a rate higher by nearly one half than that paid by the wealthiest nobleman in England, for his seat in the most luxurious railway express carriage! Besides the mail coaches, there is no other than the private or hired coach, and the rider on horse-back. It is not to be wondered at that crowds of natives are met on the road walking with their bundles over their shoulders. It is the calculation of one of the shrewdest Moormen (merchant tradesmen) of Kandy, that it costs a native 4s. at the very lowest to go to Colombo to do his business there, while, if he trusts to an intermediary broker, he pays dearly for it.

Besides the numerous passengers whom ordinary business induces, and the high prices of conveyance force to go on the tramp—there are at certain seasons crowds of pilgrims who congregate from different quarters to visit sacred places, one of which is a temple near Colombo, and another at Kandy.

The coolies, who now incur a frightful land journey from Manaar to the Central Province, averaging more than 160 miles, may be saved both time and expense, as well as fatigue and waste of life, by taking to the railway.

From these elements, and allowing for the usual "railway increase" only on the coach and private travelling, I make a total of nearly £26,000 per annum that may be derived from passengers, provided that the trains are arranged and the fares adjusted so as to suit the times and means of travellers.

Thus, I get a total of about £111,538 per annum as the revenue to be earned during the first year or two of railway travelling, when the entire Line shall be open between Kandy and Colombo.

Now, on checking this by two methods, namely, by the earnings per train mile run which are made on the partially opened Madras Railway, (65 miles), and by the Tolls received on the Kandy and Colombo Road, I find the mean of the two gives me about £107,000, as the probable earnings of the Ceylon Railway for 79 miles. It must be remembered that the Madras Railway is in a very crude state, recently opened, and its authorities and the Government are quarrelling like a house divided against itself; and as I am persuaded that the Turnpike Tolls give us the safest criterion by which to judge of the railway traffic, I give the case which I found on them in detail.

In 1857, the Tolls between Colombo and Kandy, at the six bars on that road alone, without taking into account any branch Tolls, have sold for £28,588 for the year. Taking into account the expenses and profit of the Lessees, the earnings of those Toll bars cannot be less than £30,000, and indeed they are put at a higher figure by the most experienced Officers of the Government, who have the charge of the Financial Department; but to stop all questions, let us take £29,000 as the earnings of the road. These Tolls have steadily increased each year up to the above figure since 1854, when they were rented for £17,678.

The Tolls are 6s. per Bandy (bullock cart) per complete journey.

The Bandy takes 15 cwt. down, and 12 cwt. up, on the average.

The journey up and down costs the person who hires or employs the Bandy from 70s. to 80s.—but say only 70s.

Thus we have Tolls paid to the extent of 12s. upon a cost of 70s., or about one-sixth as the ratio between Tolls and sums paid for carriage of goods.

The coach does not pay Toll at all, being a mail coach; but when hired as a private conveyance, it pays, (or ought to pay) 24s. for the double journey, for which the hire is £20, or about one-seventeenth as the ratio of Toll to cost.

A horse hired to ride would give about one-seventh as the ratio of Toll to cost.

But if we take no ratio higher than the Bandy ratio, (which is the lowest) we get £29,000 × 6, or £174,000, as the cost paid by the public for conveyance between Kandy and Colombo per annum, and exclusive of any mail coach traffic. Say that one-fourth of this will still be paid for ordinary conveyance by road when the Railway is made: then the balance thus left for the railway is £130,500 per annum.

No case of traffic, that I know of, exists where *less* is paid, since the opening of a railway through its district, than was paid before such railway was established; but notoriously *more* is always paid for locomotion by the public after such railway has been established.

From these three analyses, viz:—The detailed calculations which produce £111,538—the Turnpike Tolls, which lead us to see the way to £130,500; and the comparison of those Tolls with the Madras mileage earnings, which give us £107,000; my conclusion is that I am not far wrong in putting the earnings of the railway, for the first two years after complete opening, at about £111,538 per annum, and that after that period its traffic will increase rapidly to the larger figures shewn by the Turnpike Tolls.

After this we must consider the probable expense of working the railway, which expense must be deducted from the earnings before any dividend can be paid. I am of opinion that no estimate is to be relied on of working expenses founded on a per centage of earnings. Upon a small or ill-conducted traffic, or one with light passengers and heavy goods, the expenses will be at a higher per centage than on a railway better managed and more favourably circumstanced. I think the Ceylon Railway will be less favourably circumstanced than the Indian Railways, in so far as the proportion of work done (or miles run) with goods will be larger than that done with passengers; still I do not think the expenses taken as a per centage of earnings ought to come up so high as 50 per cent. Taking 48 per cent. as the probable figure, the expenses on £111,538 would be about £53,000 per annum.

Again, checking this by the mileage, I think the Ceylon Railway will require to run nearly 300,000 train miles per annum, taking the present cost of the Indian Railways at 1½ rupee per train mile (which I believe they really are working at) and adding to this one-sixth for the preponderance of goods trains on the Ceylon Railway—we get the sum of £52,500 per annum, as the probable amount of working expenses for a traffic earning £111,538 per annum. I believe this is as truthful an approximation as can be at present arrived at. The surplus is, of course, the sum available for re-payment of guaranteed dividend.

I have now only to notice that part of my instructions which desires that I should "give due consideration to Mr. Drane's Line." I would rather have left this subject in silence, but the mode in which that Line was reported upon, and very nearly adopted, involves such false principle that I must not shrink from stating the result of the consideration I have given to it.

Mr. Drane, a young assistant Engineer at the time he surveyed this Line, deserves credit for having selected the best general tract for his Line that the country afforded between the rivers Kalany and Mahavilla. But there were no commercial termini to the Line; the Plans and Sections agree with the information given to me on each spot where they terminate—seven miles from Colombo, in a jungle on the river Kalany at one end, and three miles from Kandy at the other end, in open ground—near, but not on the turnpike road.

The Chief Engineer of this Line knew nothing of the country from personal observation; and his Report both mystifies and misstates the position of these termini. I must also declare my conviction—after examining the ground with the Plan and Sections before me—that the ground in several places (and I allude more particularly to the Section representing the Line in the basin of the Maha Oya, and in the dell of the Upper Hingoola), cannot be found as there shewn, and that, consequently, the Estimates had no reliable basis. In fact, the detailed Report and the Plans and Sections disagree among themselves, the statistics of traffic were all but worthless, and the interests of the Company and of the Island have fortunately escaped from the inevitable consequences of beginning a work of magnitude upon such data, which would have involved an expenditure of fully a quarter of a million more than I have recommended in this Report.

I wish not to be mistaken while expressing these strong remarks—Mr. Drane acted well in the position of a Surveyor; but to place the Line in the hands of a Chief Engineer who had never seen the country, and knew nothing personally of the material to use, and the resources to apply in that country, was a gross error of principle from which the Company may be thankful they have escaped. May they be thus fairly warned for the future.

I cannot conclude this Report without expressing publicly to the several Officers of Government, as well as to every individual whom I have addressed for information, my acknowledgments in return for the prompt and efficient manner in which Maps and Statistical papers, as well as the prices and specifications of various local Works, have been placed by them at my disposal. The labour of compiling these has been considerable, and I can only hope these gentlemen will perceive that valuable service to the Island has resulted from the analyses of their Returns, which are embodied in this Report. Every facility has also been afforded to the Surveyors, and aid in lodging and provisions, frequently and freely extended to them, by the hospitality of the Planters in the neighbourhood of their work, which has comprised 120 miles of trial Sections, and in addition about 160 miles of flying levels, much of the work having been cut through dense jungle, and under the intense heats of the hottest season in Ceylon, during which the Surveyors have been so providentially spared that not one case of serious illness has been experienced throughout their arduous service.

The valuation of Lands and Property required for the railway has been made by Mr. Bailey, for the Western Province, under direction of Mr. Layard, and by Mr. Adams, for the Central Province, under direction of Mr. Power; and I beg to express my thanks for the ready manner in which this service has been performed. The sum estimated, and allowed by Government for this Survey, has not yet been worked up to, and when the expedition shall have finally returned to England, I believe I am correct in saying that, without trenching upon the contingent fund, the Survey will have been completed within the estimates by about five per cent.: and this is the best earnest I can give that the railway, if properly handled, will be constructed within the sum named in my estimates.

The documents which accompany this Report, are—

Notes in Appendix on the Agreement with the Railway Company.
General Plan, to illustrate the Routes stated.
Detailed Plan of Terminus at Colombo.
Do. do. do at Kandy.
Section of the whole of the Railway from St. Thomas's, Colombo, to the Post Office, Kandy.

I have the honor to be,
Sir Henry,
Your very obedient and faithful Servant,

W. S. MOORSOM,
Chief. Engr. Govt. Railway Survey.
17A, *Great George Street, Westminster.*

Notes on the Mode of Executing the Survey.

By LIEUT. FESTING, Royal Engineers.

In December, 1856, Captain Moorsom, a member of the Institution of Civil Engineers, was appointed by the Secretary of State for the Colonies to proceed to Ceylon in order to survey the country between Colombo and Kandy, and determine upon the best line for a railway between those termini.

A line of railway had been previously surveyed between the same termini by the Ceylon Railway Company in the year 1847, after which the project seems to have fallen into abeyance until, as the result of protracted negotiation, the Company were able to obtain a guarantee of dividend from the Ceylon government under the active administration of Sir Henry Ward. But the survey was supposed to be superficial, and the estimates incomplete, and as it was agreed that the revenue of the island should be the means of securing the guarantee to the Company, it became desirable to ascertain by means of an engineer independent of the Railway Company, and acting with the authority of government, how far the measure contemplated was feasible both in an engineering and in a financial point of view.

To this expedition I was appointed Secretary by the kindness of the Inspector General of Fortifications, under approval of the Commander in Chief, on the application of Captain Moorsom to that effect, and having thus had the opportunity of taking part in a survey carried out upon a large scale which is seldom afforded to officers of the Corps of Royal Engineers, I have been advised to communicate, for the benefit of those who may be hereafter engaged in similar services, some notes of the details of its progress.

The expedition was proposed about the middle of December, 1856, and it was the 24th of that month before any authority was given for acting. Upon conferring with those who were conversant with the climate of Ceylon it seemed to be the general opinion that after the middle of May the weather could not be depended upon for working in the field, as the South-West Monsoon has usually set in by that time with heavy gales and torrents of rain. On the other hand, should the survey be delayed beyond this rainy season it was evident that not only would considerable expense be incurred in the survey itself but that the loss of time would be a serious injury both to the Railway Company and to the accommodation of the island.

The first problem therefore to engage the attention of the engineer was how to accomplish, within a space of less than 5 months, a survey at a distance of more than 6,000 miles from home, for a line of railway between two termini 80 miles asunder, and with an intermediate country represented as mountainous and to a great extent covered with jungle.

In Europe it is usual to consider that for every mile in a direct line 3 times the length will have to be levelled over; thus about 250 miles of levels were expected to be requisite in this instance. In Europe also it is usual to calculate that from 1 to 3 miles per day of finished levels may be run by each surveyor; but in Ceylon the comparatively impenetrable nature of the country rendered the usual calculation of little avail, and it was estimated that not more than ½ a mile per man per diem could be executed, on the average of both trial and finished levels, in such a country as it was represented would be found there.

On this basis a staff was organized, consisting of 8 levellers (who were also capable of making such surveys as were necessary), a secretary, and a foreman intended to superintend labourers in the jungle. To these were to be added such labourers and overlookers, and such assistance in draughtsmen as might be afterwards necessary, and who, it was supposed, would be found in the island. The strength added from this source was one officer (Lieut. Moorsom, H.M's. 52nd Light Infantry) who joined from India and was employed as surveyor and draughtsman during nearly a month, and one draughtsman, with some occasional assistance, from the offices of Major Skinner, Civil Engineer, and Captain Gosset, Surveyor General of the island.

Reckoning therefore six levels in the field, and two as a reserve, it resulted that three miles a day might be accomplished, or 78 miles in 26 working days per month. Thus 250 miles would occupy a little more than 3 months. Fortunately no case of serious illness occurred among the surveyors, and the reserve levels which had been provided for such emergency were employed to a great extent in advancing the general progress, so that in just three months from the time of planting the first level near Colombo the final levels were completed in the dell of the Gadadessa near Kandy.

Execution of the Survey.

The expedition was despatched in three divisions. The first, consisting of five levels, embarked on the 4th of January and began their field work at Colombo on the 9th of February, under the principal surveyor, whose directions on leaving England contemplated that his strength should be distributed along the flat country extending for about 40 miles between Colombo and the hills, in order to advance as much as possible the progress of the sections over this comparatively easy country, while he himself should examine the hills generally to seek out those passes which might be worthy of more critical examination, by the time the chief engineer should arrive to examine them himself.

To aid the principal surveyor in his examination in the hills solely, the second division was assigned. This division, consisting of three levels, left England on the 20th of January, and commenced their work in the hills on the 9th of March.

It was calculated that by the time the chief engineer with the third division should arrive in the island, the levels would be sufficiently advanced both in the low countries and in the hills to enable him to decide on rejecting the least favourable lines, leaving probably only one or two passes for more detailed examination. The third division, leaving England on the 4th of February, arrived in Colombo on the 13th of March. It was then found that the respective levels had advanced very nearly to the stages contemplated for each division About ten miles of section in the lower country near Colombo was abandoned in consequence of the engineer finding that a better terminus could be obtained than that which had been pointed out in the Railway Company's survey; and in consequence of this, instead of being able to withdraw all the levellers at once from the low grounds to the hills, two levels were employed for another fortnight in connecting the terminus, as then arranged, with the further portions of the line which still remained available.

A length of about 35 miles out of Colombo being thus found available for any line which might be selected beyond that distance, I accompanied the chief engineer to the hills, and our Aneroids were immediately set to work in order to examine comparatively both those passes which had been observed by the principal surveyor, and those which, by continually riding or walking over the ranges, presented themselves to us as worthy of observation.

As a copy of the report is appended to this paper I need not specify the character of these passes, nine in number, or their levels, but it may be here noted that they are spread over a tract about 81 miles long, extending from Ambokka on the north to

Genegathenia on the south. The number of observations made to determine the relative heights of points affecting the gradients to these passes and the character of the works required upon each line was 280, besides those which were taken for the purpose of determining the diurnal variation Two instruments, which read to ·005 inch, were used. These observations occupied about a month, and about 600 miles were travelled over in order to make them, and at the same time to obtain such a knowledge of the features surrounding the passes as would enable a judgment to be formed as to their relative capabilities. It then became evident that the line alluded to in the report as that by way of Gordon's Bridge and Parnepettia presented more favourable features than the others, and as the levellers came in from the low country and the other passes of the hills on which they had been respectively employed, they were thrown upon this line. Thus by the middle of April 6 levels were concentrated on 25 miles of this line between Kandy and the lower country.

The progress over this portion however was excessively slow, as almost every yard had to be cut through jungle of a very tangled description The levellers had to work in duplicate, that is to say, the explorer who directed the cutting, and took the first levels in rough, was immediately followed by a leveller who set out the curves and made the final section, and each of these parties, with from 10 to upwards of 20 "catty" (axe) men, employed in cutting the jungle before them, made at the best only three miles, and sometimes only one mile per week of six days.

With the exertions used all the sections were completed by the end of April, with the exception of about two miles in the upper valley of the Gadadessa. Here the valley rises with a wedge-like character more than 500 feet from the bed of the river to the top of its bounding ridges, while the bed of the river itself about the place in question falls about 120 feet in a quarter of a mile. The spurs of the ridges also protrude in a very irregular manner, and three different sections were found necessary before it could be ascertained that a fair working line of railway could be obtained in this direction. Seven levels were employed during the last week upon this small portion, and it was not before the 14th of May that the final section came in.

The sections were plotted upon a scale of 4 inches to the mile horizontal, and 100 feet to the inch vertical, and the plans shewing the course of these sections varied in their scales from 20 inches to 4 inches to the mile.

The "Young Monsoon" commenced on the 22nd of April, after which we could only reckon upon the forenoons without rain, and about the 20th of May the regular Monsoon had set in.

Meantime, since the early part of April, when the plans and sections of the lower grounds had been received, the calculations of the quantities of work had been in progress. These included the necessary earthworks, as well as bridges, viaducts and culverts, and each surveyor as he came up to head quarters gave in his statement and verbal explanations of the waterways required for culverts, and of other local features affecting the works and estimates. Thus in fact, the calculations proceeded *pari passu* with the receipt of the different sections, and on the 16th of May the whole of the plans and sections required for presentation to the Governor of Ceylon were in readiness, with duplicates for retention in the office, the report accompanying them was in print, and on the 18th the whole were presented to the Governor in Kandy.

Having thus described the engineering arrangements of this survey, it becomes necessary to advert to the statistics of the railway.

Parties in the island having different interests had been carrying on for a long time a paper warfare as to the best direction for the railway in a commercial point of view, and it was evident that the traffic, which might be obtained on this line or that, would form a very important consideration, as well as the cost to be incurred in construction

Fortunately in Ceylon the system of government comprises the preparation of returns by which the traffic on each road is intimately known, as well as the inward and outward trade by the usual Custom House documents at each port. Returns were therefore obtained of all the traffic on each of the roads and one river, five in all, by which trade is carried on between Colombo and the interior towards or beyond Kandy. The opinions of the Government agents were taken as to future extension of traffic, and the views of the planters were consulted as to the present and future produce of estates and the labour and manures required for them. The population of the districts was obtained within those areas which any railway might accommodate, and the statistics of the Madras railways, as being nearest at hand, and therefore the most likely to form a just comparison, were examined, in order to check by comparison the results deduced from the returns in question. The labour of collecting these was considerable, and the results only are indicated in the report. These were deemed so satisfactory by the Governor that his proclamation was issued within five days after the presentation of the report, announcing that the agreement with the Railway Company would immediately come into operation.

On the 29th of May the whole of the expedition re-embarked for England.

Aneroids.

As the observations made with the Aneroid in this instance were probably more extended than have hitherto come under the notice of the Corps some remarks upon them may be interesting.*

The great difficulty with which we had to contend was the difference of reading of the Aneroid at the same place at different times. This we found to be be principally attributable to the variation which always exists daily in the height of any barometer, or which may be termed diurnal variation.

By taking half hourly observations with the same instrument at the same place we found that at Kadoganawa (the datum to which most of our observations were referred)† the difference between daylight, about 5·30 a.m., and 9 a.m., about which time the barometer reached its maximum, was from ·05 to ·075 inch; between 9 a.m. and 3 p.m., at which latter time it reached its maximum, the fall was from ·115 to ·14 inch. At higher elevations the diurnal variation was found to be considerably less; for instance at Newera Ellia (6,400 feet above the sea) the variation from 5·30 to 9 a.m. was from ·02 to ·03 inch, and from 9 a.m. to 3 p.m. from ·075 to ·09in.

As the variation differed locally it was evidently impossible to obtain accurate results at places far distant from each other, even with two instruments, one being stationary during the day while the other was travelling. But with a stationary instrument at a point not far removed from the point where observations were taken with another instrument, or when the observations were near together in point of time, and made with the same instrument, in both cases satisfactory results were obtained, as was proved by the spirit levels carried to those points; and there are few circumstances under which the Aneroid cannot prove a valuable auxiliary in determining comparative levels within certain reliable limits. Of course the observations made were always corrected for diurnal variation where such correction was obtainable.

* An account of the Aneroid will be found in the British Aide Memoire Vol. II. p. 418.—*Ed.*

† Here stands a column erected to the memory of Captain W. F. Dawson, Royal Engineers, who died at Colombo in 1829 (see p. 67, Vol. I, of this Series), and who planned the great roads constructed by the British Government after they obtained possession of the Central Provinces; and it may also be observed that the science of Engineering was applied in this country in very ancient times to the construction of enormous dams and sluices for the purpose of irrigation, which it is now intended to render again available, and which will perhaps not be surpassed in magnitude by the railway works now projected.—*Ed.*

We had no time to make experimental observations which should be afterwards checked by spirit levels, and therefore we could not decide as to which of two or three methods recommended by different writers was the best, nor could we discover from what source the further variation of the Aneroids arose, but temperature seemed to have something to do with it, although both our instruments were supposed to be compensated for temperature. We found also that our instruments did not agree either in their general height or in their respective variations.

The following table shews the result of five days' observation of the diurnal variation with stationary instruments at Kadoganawa Rest House, at an elevation of 1745 feet above the sea.

Time.	Readings of the Aneroids.				
	Instrument A.				Inst. B.
	March 24th	March 25th	March 28th	April 6th	March 26th
5·30 a.m.	28·215 in.	28·225 in.	28·205 in.	28·200 in.	27·790 in.
6·0	28·210	28·235	28·215	28·230	27·800
6·30	28·210	28·245	28·225	28·260	27·815
7·0	28·235	28·250	28·235	28·280	27·830
7·30	28·245	28·255	28·245	28·285	27·835
8·0	28·255	28·265	28·255	28·300	27·840
8 30	28·270	28·275	28·265	28·290	27·845
9·0	28·275	28·285	28·270	28·290	27·850
9·30	28·275	28·290	28·265	28·295	27·845
10·0	28·270	28·280	28·260	28·290	27·840
10.30	28·255	28·270	28·250	28·280	27·835
11·0	28·245	28·260	28·240	28.265	27·835
11·30	28·225	28·250	28·230	28·255	27·820
12·noon	28·210	28·240	28·215	28·245	27·805
12·30 p·m	28·195	28·220	28·200	28·235	27·790
1·0	28·185	28·210	28·190	28·220	27·785
1.30	28·175	28·195	28·180	28·210	27·775
2·0	28·165	28·180	——	28·195	27·760
2·30	28·155	28 180	——	28·185	27·745
3·0	28·150	——	28·140	28·175	27·730
3·30	28·135	——	28·145	28·165	27·730
4·0	28·135	——	28·150	28·165	27·735
4·30	28·140	——	28·150	28·170	27·740
5·0	28·150	——	28 150	28·180	27·745
5·30	28·160	——	——	28·190	27·750
6·0	28·175	——	——	28·200	27·765
6·30	28·190	——	——	28·210	27·790

In this table it will be seen that the instrument A was standing about .4 of an inch higher throughout than B.

Schmalcalder's Plummet Level.

Another instrument used by the chief engineer on this occasion, which may not be generally known, was Schmalcalder's plummet level.

A circular brass box with a glass face, about 4 inches in diameter, and therefore very portable, contained a circle with a silver rim graduated to degrees and thirds of a degree, and read by a prism. In this circle was imbedded a plummet which, when the instrument was held vertically, indicated the nadir beneath its own centre, the circle being perforated by a spindle nicely poised on hard metal bearings. The usual sight and horse-hair lines cut the centre of this circle; thus any angles of elevation or depression could easily be obtained by making the hair coincide with any graduation on the rim.

The great use of the instrument was found to be in ascertaining from points of level already known the corresponding levels on distant hills, or along the sides of valleys up which trial levels might be desired, which was done by directing the sight so that the horsehair cut zero on the circle. Many useless series of trial levels were thus dispensed with, which a judgment formed with the eye alone might have incurred.

Cost of the Survey.

I here append the estimate and actual expenditure for the survey.

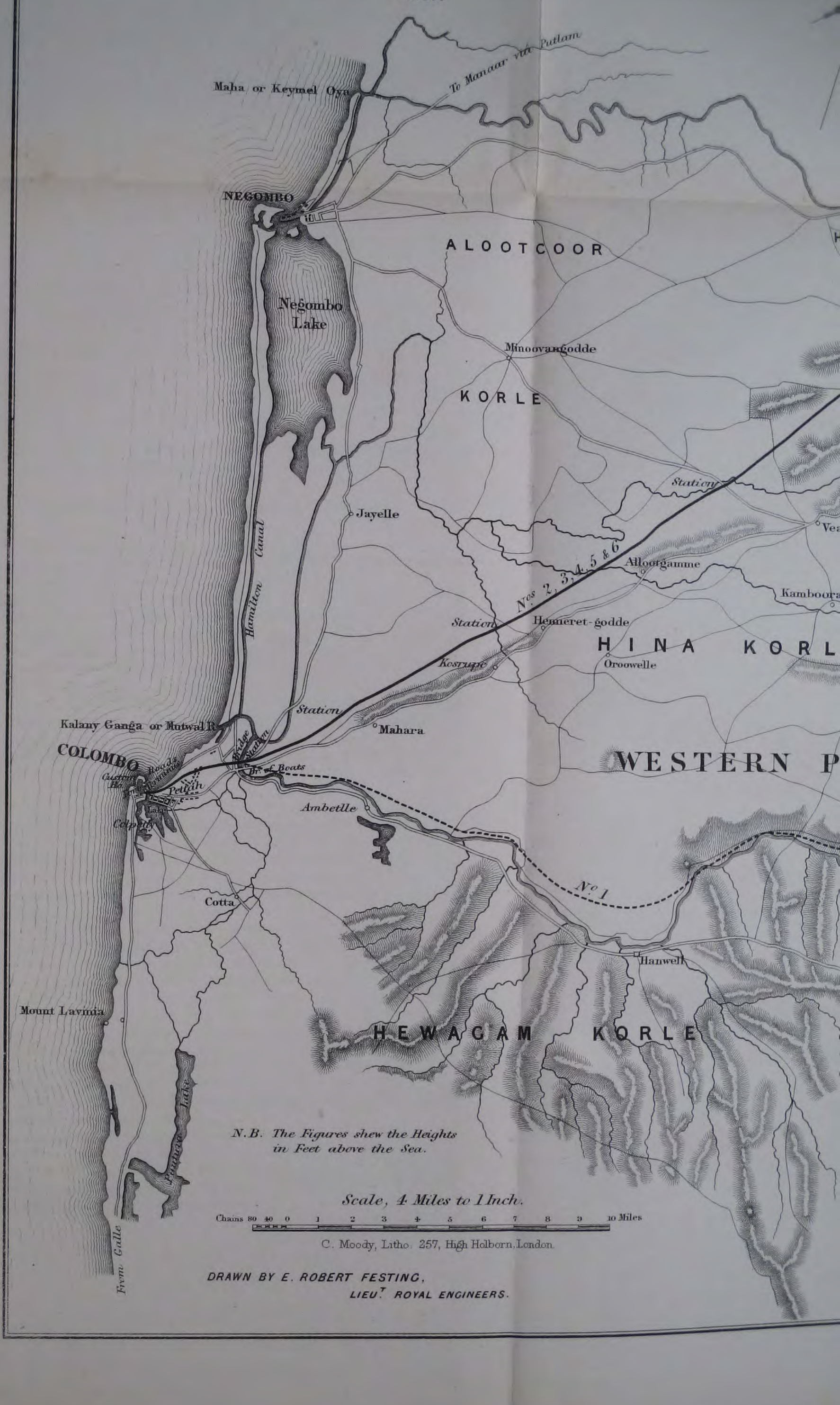
Estimate of Expenses.

Dec. 1856.	£	s.	d.
Salaries	5,775	10	0
Passages	4,407	0	0
Travelling Expenses	2,280	0	0
Contingent for unforeseen Expenses	946	5	0
Total	10,408	15	0

Actual Expenditure.

July, 1857	£	s.	d.
Salaries..	5,649	10	6
Passages	1,273	0	0
Travelling Expenses	2,110	6	3
Contingent (for Maps, &c.)	80	14	0
Total	9,113	10	9
Less a credit for horses, carriages, and other stores for travelling—purchased for about £400, and supposed to be likely to realize	£200	0	0

1857.


Maha or Keymel Oya
To Manaar via Putlam
NEGOMBO
ALOOTCOOR
Negombo Lake
Minoovangodde
KORLE
Station
Jayelle
Hamilton Canal
Nos 2, 3, 4, 5 & 6
Alloorgamme
Kamboora
Station
Hemeret-godde
HINA KORL
Kosrupe
Oroowelle
Station
Kalany Ganga or Mutwal R.
Mahara
COLOMBO
Bridge
Station
Br. of Boats
Pettah
WESTERN P
Ambetlle
Colpitty
No 1
Cotta
Hanwell
Mount Lavinia
HEWAGAM KORLE
From Galle
N.B. The Figures shew the Heights in Feet above the Sea.
Scale, 4 Miles to 1 Inch.
Chains 80 40 0 1 2 3 4 5 6 7 8 9 10 Miles
C. Moody, Litho. 257, High Holborn, London.
DRAWN BY E. ROBERT FESTING, LIEUT. ROYAL ENGINEERS.

PAPER III.

On the Influence of Fortifications of considerable extent upon Military Operations: A Fragment.

By Major-General Lewis, C.B., Royal Engineers.

In order to bring home to the mind this influence we will commence with Delhi, and then go back to other fortresses of recent celebrity, viz., Sebastopol and Kars, Silistria on the Danube ; and also Verona and Mantua in Italy.

Delhi, in Upper India, a Mahometan city, fortified and adorned by Ackbar, has been the refuge of the mutinous army of Bengal, and has only been taken after three months' blockade and a short siege, whilst during this time it has paralyzed the operations of the British Army, and rendered the mutiny more complete in other portions of Bengal.

Sebastopol certainly saved the Crimea, and prevented the war being carried into the heart of Russia ; and although the fortifications enclosing the Dockyard were only works of the moment, connected with a slight enceinte surrounding the town, it formed a field fortress of great strength, and being garrisoned by an army, and by 12,000 seamen accustomed to manœuvre heavy artillery, it took ten months to reduce it ; hence its value to Russia in securing an honourable peace, besides absorbing nearly all the maritime and military strength of three empires, viz. France, Turkey, and England, on one spot.

Kars, by the defence of works thrown up in haste, forming rather emplacements for artillery than redoubts, and by the peculiarity of its position, enabled a Turkish force to resist a large disciplined Russian army (see Paper VI. in the 6th vol. of these Papers.) The fortifications were so placed as to make the whole a respectable field fortress, only to be reduced by starvation, and by the want of those military resources necessary to the defence of a fortress; and it so far realized its object as to save the Turkish Pashalicks of Trebizond and Erzeroum for that season.

The defence of the fortress of Silistria on the Danube was the turning point in the late war with Russia (see Paper XVII. in the 6th vol. of these Papers) and turned a war of defence into an offensive one, rendering the position of Constantinople secure from all danger; and the Allies were thus enabled to transport their forces to the Crimea, and to relieve the Turkish Provinces from the evil of being the seat of war, by carrying it into the enemy's country. The successful defence of Silistria, the first of importance in the late war, may be deemed also a prominent example of the power of fortified places in controlling military operations, and influencing the movements of troops, which it is the object of this paper to call attention to. The history of the events here alluded to is so recent and so patent to every body that it is unnecessary to enter into details of the operations of the armies either preceding or following the defences of the places above mentioned.

It is about ten years since France and Italy were convulsed by an outbreak, and by disturbances of their Governments which induced the King of Sardinia to invade Lombardy with a considerable force, and at first with some success, for he obliged the Austrians to retire towards the Tyrol under the protection of the fortresses of Verona, Peschiera, and Mantua, and wait for reinforcements.

The Sardinian army made some futile attempts on Peschiera, but made no serious attack on Verona or Mantua.

It may be remembered (See 4th Vol. of the first Series of these Papers) that the Austrians had fortified the position near Verona with towers projected by the Archduke Maximilian, then Chief Engineer in the Austrian service, and that they had formed an intrenched camp under the protection of these towers. Here the Austrian army waited for reinforcements, and on the Adige the Sardinian army exhausted all its strength, and was obliged to retreat. It is unnecessary to enter into the details of the movements of the Sardinian army, composed chiefly of raw recruits and undisciplined Italian patriots; it suffices to say that it was beaten, and that the King of Sardinia gladly accepted a truce, and a termination of hostilities.

This campaign is alluded to in order to explain the advantages of the works at Verona, supported by the two fortresses of Peschiera and Mantua, which certainly saved the Italian Provinces of the Austrian empire at that time.

Recurring to a more remote period, that of the war which terminated in 1815, only isolated examples can be brought forward. The previous twenty years was a period of almost uninterrupted demoralization of the social system of Europe; and hence patriotism and loyalty were rarely displayed, and the bad defences of places brought the art of fortification into low esteem, The exception was always in favour of the French army, which never lost sight of what was due to itself or to France; and, however isolated their position, the French soldiers always made a defence commensurate with their means. At the close of the war in 1814 and '15, however, the French fortresses were denuded of garrisons, and the places were left with nothing but a few National Guards and invalid soldiers, hence during that period no defence worthy of record took place.

In our military history, we have the Peninsular Campaigns for examples, during which the fortresses of Ciudad Rodrigo, Badajos, and Burgos greatly influenced the military operations of both armies.

We may refer to Badajos in particular. This place, situated on the Guadiana river, in the province of Estremadura, in the course of three years underwent four sieges. In 1810, it was necessary to Marshal Soult to secure his conquests in Andalusia; when he attacked it the Spaniards made an indifferent defence, and Wellington, pressed upon by Massena, on its capitulation was obliged to retreat upon the lines of Lisbon.

When Massena failed in his attempt to gain Portugal, and was compelled to abandon his conquests in 1811, and Wellington resumed his former positions on the frontier, Badajos became the objective point to secure his progress; but, having a French garrison, two unsuccessful attacks were made on the fortress by the British troops.

In 1812, when Buonaparte withdrew the elite of his forces from Spain, and gave the Duke of Wellington an opportunity to enter Spain, the possession of Badajos became essential to secure his advance, and in the spring of that year he took the place, with great loss of life and after five weeks of open trenches.

We are all aware that this conquest led to the victory of Salamanca, the possession of Madrid, and the evacuation of the South of Spain by Marshal Soult; and that the subsequent attack by Wellington on the field fortress of Burgos (where he wasted 6 or 7 weeks in siege operations) failed, and led to a disastrous retreat into Portugal.

These sieges are only alluded to as examples of the influence of fortification upon military operations, not in order to comment on the mode of conducting them, but to show the vast importance of fortified places.

In giving the examples of Delhi in India; Sebastopol, Kars, and Silistria, in the East; Verona, &c., in Italy; and Badajos and Burgos in Spain, it should be observed that systems of fortification have had no influence in the memorable defences made by their garrisons. And hence the Engineer should divest himself of prejudices in favour of schemes, when the nature of the ground, position of the proposed works, and object in view should only be considered for the formation of a strategical fortress, intrenched camp, or place du moment. The suggestions offered by the writer in previous volumes of the Corps Papers for building fortified places for the defence of the country to the South of London have been based upon the probable influence they would have, in the event of a hostile force having landed on the Southern shores of England with the object of taking London.

Many persons suppose that fortified places must be walked over to be of any use, that is, form an absolute barrier to the advance of an enemy; but this does not embrace all their advantages: in an open frontier, two or three fortified places, 8 or 10 leagues apart, would impede, if not obstruct, the advance of an enemy, by their garrisons cutting off his supplies, and acting on his flanks and rear, so as to oblige him to mask the place or places with a superior force and weaken his army, which may give the retreating forces the power to offer battle and turn defensive operations into offensive ones.

In an open country, for example that between the River Medway and Portsmouth, intersected with excellent roads, both lateral and converging on London, two fortified places capable of containing a considerable garrison of all arms would afford the means of checking the advance on London, and, as before observed, perhaps so reduce an enemy's force as to render the final attack on London impracticable; and should a retreat become necessary the fortresses in his rear would make that operation very difficult, if not disastrous.

On the Continent, so impressed are the governments with the influence of large fortifications upon military operations, that the Germans have constructed very extensive works at Rastadt near the Rhine, and at Verona in Italy; and the French have done the same at Grenoble in the South-East of France; the Sardinians are re-constructing Alessandria in Piedmont, and the Prussians are strengthening Cologne: the Belgians have also selected the position of Antwerp, where they are building extensive works, to make their last stand upon; but fortification, as a science, or its application to the defence of states in connection with military operations, is not valued in this country because it is not generally understood. Yet it has been applicable in all ages, and the siege of Syracuse by the Athenians, between 2,000 and 3,000 years ago, is a memorable example of the value of fortifications as the means of saving a state.

G. G. L.

Belwood, Winchfield, Hants, 4th December, 1857.

PAPER IV.

Account of the Mode of Employing Screw-Piles to Anchor Brushwood for the Protection of the Bank of the Rutmoo River, contained in a Letter to Colonel Sandham, R.E.

By MAJOR ALFRED GOODWYN, Bengal Engineers.

Scarborough, 29th July, 1857.

My Dear Sandham,

When at Chatham I had some conversation with you regarding the manner in which small screw-piles had been used in India to anchor masses of brushwood for the purpose of regulating the course of rivers. You asked me for the substance of that conversation in writing, and I have much pleasure in sending it.

The merit of the idea of thus using brushwood lies with an indigo planter, of whose name and many details I am ignorant. His factory stood on the bank of a river which was being gradually cut away by the action of the current, and it occurred to him that if he anchored large masses of brushwood opposite to his factory he might save it. The experiment was tried and answered.

The way in which the brushwood acted was no doubt as follows: almost all Indian rivers carry with them in suspension large quantities of silt, more especially during the rainy season, and this quantity of course varies with the soil draining into the river, with the slope of the river's bed, and with its depth. If the depths of streams are the same their powers of abrasion are as their velocities. I believe that in the case of a river charged with silt, the water during its course to the sea is constantly depositing some particles of silt and picking up not quite so many others. I here allude to the passage of rivers through alluvial plains.

When the velocity of water bearing silt is checked, a deposit will take place. This is notorious—take the case of any silt-bearing torrent whose bed has, say, a slope of 15 feet in the mile. Make a channel branching off from it with a slope of, say, 3 feet in the mile, and see what will happen—such channel's mouth will be closed by silt in a few hours. It is very well known that such silt-bearing torrents do not run along the lowest levels of valleys. They once did so, but soon raised their own beds, and by their overflow their banks also, and will continue this course of self-exaltation as long as the number of particles deposited in their course exceeds that of the particles picked up. The valley of the Indus is an example of this on a large scale.

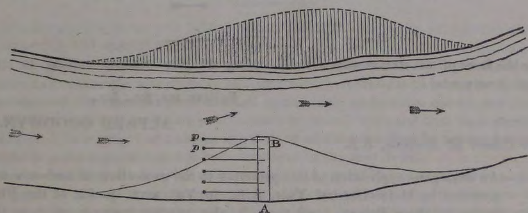
In the case of the factory, the brushwood caused a diminution of the velocity of the current beneath, in front, and behind it, up stream and down stream; silt immediately fell to the bottom, a shallow, and eventually a bank, was formed, and the factory was saved.

With the indigo planter's example before him, Mr. Thomas Login, one of my assistants on the Ganges Canal, and a gentleman of very great *resource*, with the sanction of Colonel Sir Proby Cautley, the Director of the works, proceeded to turn the course of the Rutmoo Torrent, which takes its rise in the Sewalik Range at the foot of the Himalayas. In the dry season hardly any water remains in the bed of this river, which has a slope of 7 feet in the mile near our works. After heavy rain floods come down most furiously. I estimate them sometimes as equal in discharge to that of the Thames at London Bridge, with about $2\frac{1}{2}$ times its velocity. The bed is full of quicksands formed by vegetable and earthy matter mixed with detritus of the loose crumbly sandstone of the Sewaliks. Occasionally forest trees are dashed down as the banks on which they stand are undermined.

The object was to throw the current off the bank A.

FIG. 1.

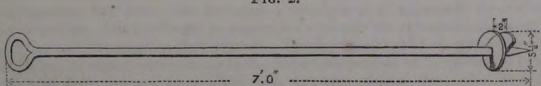
N.B. The shaded part was cut away by the stream.



For this purpose masses of brushwood, such as thorn bushes and the like, perhaps in all 10 feet wide, and corresponding in height with the section of the river at A, were laid in the direction AB, during the fine weather, and anchored to the heads of screw-piles p, p, p, by pieces of condemned chain about 40 feet long. I dare say that rope would have done nearly as well, but instances have been known of small forked branches of trees getting astride of similar rope moorings and sawing them through: having, then, a stock of condemned chain we used it. Mr. Login thought that an action of the current might take place immediately at the foot of the brushwood, and preferred anchoring it to pinning it down.

The screw-piles were about 7 feet long, of $\frac{7}{8}$ inch or 1 inch round iron, the screw being, say, $5\frac{1}{2}$ inches in diameter, formed of sheet iron $\frac{1}{8}$ inch thick, and with, perhaps, 2 inches pitch. Each rod was pointed at the lower end, and formed roughly into an eye at the top, thus:

FIG. 2.

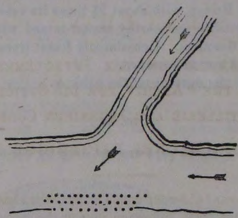


The piles were screwed into their places, with hardly any exertion of strength, by means of handspikes.

The result was most satisfactory: the very first flood formed a bank, as shewn by the thin line, and the current was thrown over to the other side. Screw-piles, chains and all were covered with silt, as also the greatest part of the brushwood.

We had not occasion to try this plan again during my stay on the Ganges Canal, but I have the most perfect confidence in its success.

Akin to it is the Italian method of protecting banks by what I believe they term "elastic piling," thus:—



Here the force of the stream wastes itself among the piles without cutting to any extent downwards.

Believe me, &c., &c.,

ALFRED GOODWYN.

To Colonel H. Sandham, R.E.

NOTE.—An analogous application of this principle to the protection of harbours was proposed by Major-General Yule, R.E., in Vol. VIII., p. 82, of the First Series of these Papers; and there is also another instance of it in the system adopted for improving the channel of the Danube in those parts of it which are broad and shallow. Dams, formed of fascines, are constructed at intervals, and in lines extending from the banks to the edges of the channel required to be deepened, which check the current so that the silt is deposited on the shallow parts at each side (and these may even be *reclaimed*), whilst the force of the stream is directed along the channel, which is thus scoured and deepened at a moderate cost.—ED.

PAPER V.

Extracts from Remarks on the Improvements in Permanent Fortification, in the "Archiv für die Officiere der Königlich Preussischen Artillerie and Ingenieur Corps."

Translated by LIEUT.-COLONEL BAINBRIGGE, Royal Engineers.

It is certain that in the year 1815 confidence in fortresses had in general diminished, because they had exerted but little influence during the previous 10 years, and had also often made but little resistance. Napoleon's system of employing overpowering masses had caused these barriers to smaller military operations to be neglected, weak governors or disorganized garrisons had opened their gates to the enemy, and people complained with justice that they were burthens to a state, and that their garrisons diminished the strength of an army when they might have thrown an overpowering weight into the scale if they had been employed in the open field.

Let us consider whether this originated in the peculiarity of construction of the fortresses, or in the circumstance that when tactics had become quite different they had been looked upon with contracted views, without due reference to their connection with the theatre of war.

We must also shew what there was which was new in the system of defence, for it became desirable to improve those parts of the old fortresses which were not adapted to the new means of attack and defence, or which did not accord with the newly defined objects of fortifying, and to build the new ones from the foundations on the same principles.

This progress, which corresponded with the changes in the state of affairs, may be best represented by dividing the subject according to the different arms employed, viz., the Infantry, Artillery, Cavalry, and Engineers ; and further, with reference to the demands for storage of provisions and ammunition, and to the tactical relations between the fortresses and the seat of war.

A. *With reference to the Artillery.*—The connection between the science of Artillery and that of Permanent Fortification has especially shewn itself latterly. The increase in the use of shells at sieges undoubtedly first gave rise to the present increased amount of bombproof cover and to the use of flanking casemates with which it is accompanied: the latter also produced a multiplicity of alterations in defensive Artillery ; and thus it became necessary to look upon the changes in the mode of fortifying with the eye of an Artilleryman. The development of Artillery also laid the foundation for many improvements in the latter, independent of its application to the defence of fortresses, and these again have not been without their effect upon the construction of modern works : thus we see how intimate is the connection between the two sciences.

1. *Influence of the changes in the Mode of Attack by Artillery upon the Buildings and Artillery employed in the Defence.*—Modern sieges have afforded fewer examples of regular attacks according to Vauban's rules than of bombardments or attacks carried on by open force and cut short by assaults and surprises.

The rapid removal of obstacles which stand in the way is a characteristic of the modern wars carried on by large masses of troops, and when this object cannot be immediately attained blockades are resorted to, whilst the general course of operations proceeds.

The art of attack of which Vauban laid the foundation, the object of which was to obtain results surely, safely, and without much loss, has given place to the opposite principle of *open force;* hence there has often not been time and means for the advancing army to obtain proper siege Artillery, and they have been obliged to be satisfied with field pieces; and hence also there have been so many bombardments, so many isolated attacks, so few regular parallels and breaches, surprises and assaults having been required instead.

The increased application of shells affects every phase of the new system of attack; shells of various calibres are showered upon works, buildings, or towns, or hurled against the besiegers at low angles, and, without going into Artillery details, we must concisely answer the question—"what has been done, as regards both the works of defence and the Artillery, to resist them?" Not only have powder magazines, a few galleries immediately connected with the defences, and some of the most exposed store-houses, been rendered bombproof, as in the older fortresses, but it has become the general rule to place barracks and store houses of all kinds in a state to resist the effects of shells. The defensive Artillery have also been rendered more capable of resisting vertical fire by the construction of mortar casemates and by the more general use of mortars in the defence, which has become necessary because the attacking Artillery are more protected against direct fire.

The unexpected and powerful effect of the Artillery fire from great distances in hurried attacks has shewn the necessity for forming long lines of rampart on which a great amount of defensive Artillery may be rapidly placed, building in front of the body of the place collateral works for taking the attacking Artillery in flank at the proper time, tracing the sides of the polygon with very obtuse salient angles, and so that their prolongations may fall upon the works in front of the rampart, or on their glacis, and giving the garrison facilities for making sorties whenever an incautious attempt is made to advance by open force. This leads to the use of long, straight, or slightly broken lines, forming the *Polygonal Trace,** with outworks in front flanked by the main work or capable of independent defence; to the replacing the old flanking bastions, for sweeping the ditch, by kaponiers built at the centre of each side of the polygon; to the extension of the sides of the polygon to 750 paces instead of 400 or 500; and to the preparation of flanking positions in the open ground in front, under the protection of the outworks, in readiness for a siege.

The more the form of the enclosure approximates to straight lines, the more easy is it to adopt the polygonal trace; in this case the kaponiers will best defend the salients between them, and they will be most covered by the redoubts in front which afford a reverse fire to their ditches: it will be more difficult when the line of enclosure is much curved, particularly in small isolated forts, the salients of which must be more acute than those of Lines: in such cases the kaponier is not placed at the centre of the side of the polygon, but in front of an angle; it is secured in front in every possible way against being breached,† and is connected with the body of the place, and con-

* See the plate at page 195, Vol 3, New Series.—Ed.

† See Note at the end of this Paper.—Ed.

structed in such a manner as to form the basis for an independent advanced cavalier. These cavaliers form the centres of the defence; the lines which lie between them may be considered as broken curtains, the flanks of which defend the kaponiers.

The collateral or advanced works exposed to hurried attacks by Artillery require above all things to be secured against assault and against vertical fire; it is of vital importance that they should have high revetted scarps, that their Artillery should be in casemates or blindages, and that they should have keeps for internal defence.

2. *Influence upon Modern Fortification of the Improvements in Defensive Artillery.*—In order to judge of this influence it is desirable to consider the latest objections which have been made by Artillery officers against the new system of fortifying with the polygonal trace.

They urge that it does not afford flank defence in itself, but requires additional works to effect that object; that it does not conveniently admit of the construction of permanent retrenchments, as it is everywhere equally exposed to be breached, that the cross fire defending the ground in front is lost, and lastly that it has long lines exposed to be enfiladed.

In reply, it may be stated that the polygonal trace need only be employed when a cross fire in front is not required, but if for any reason this trace is desirable the outline of its scarp may remain straight, whilst *that of its parapets may be varied* so as to bring their fire to bear as required; and, if exposed to enfilade, traverses of every kind may be employed: it is also evident that the evil effect of reverse fire is not experienced in this system, as it is in the flanks of bastioned fronts, and that its ramparts can generally be traced so as not to be exposed to enfilade fire.*

The defensive Artillery should be prepared to meet the increased rapidity of movement of the besieging Artillery, by improving the construction of the pieces and the mode of working them. Shells will be thrown from them not only against the howitzers and mortars of the assailants but against every mass of Artillery of any description. Every effort must be made to render light pieces of large calibre capable of producing great effect at long ranges, using those, in preference, from which both shells and shot, as well as grape, can be thrown with effect: the kinds of guns should also be reduced to the smallest number, and the calibres of those for throwing shells and of those for firing shot should be equalized.

The ramparts of the bastioned trace certainly afford flanking defence without constructing any additional works, but the kaponier attached to the polygonal enclosure enables a small force concentrated at one point to defend a long line. As the fronts of the polygonal trace may be one-third longer than those of the bastioned trace it will have the preference, all things considered, whenever it is desired to impart to long lines increased security against assault at a small cost, and either to renounce the advantage of directing a cross fire on the ground in front or to obtain this by building independent advanced works or outworks connected with the body of the place.

Retrenchments are easily formed in the polygonal system by building strong defensible barracks in rear of the obtuse angles of the rampart and connected with it near the kaponiers; or the commanding portions of the body of the place may be cut off from the rest so as to form citadels, rendering the intervening parts of less importance; or, lastly, a continuous loopholed wall may be built along the interior of the rampart.

* The outline of the works represented in the Plate in Vol. III, before mentioned, must not be taken as a correct representation of the Polygonal System, for if the angles of the polygon on the sides exposed to attack are very large and nearly *equal*, and the kaponiers are placed *at the alternate salients*, as at Rastadt, the prolongations of the ramparts cannot be taken up, and indeed the batteries to enfilade the latter could scarcely be placed as close to the ravelins as that plate represents them.—Ed.

The objections urged against the mode of flanking the ditch *by means of casemated works* are the following—by such an arrangement the free employment of the guns is prevented, and they are restricted to certain positions; the value of gun-casemates depends upon their power of resisting the effects of shot, which has not yet been positively ascertained;* in employing casemated embrasures it is scarcely possible to prevent some parts of the ditch being unseen from them; they may be blocked up by the fall of the wall above them, and hence are liable to be more easily destroyed than those in earthen works, unless they are completely covered against an enemy's fire; lastly, they cannot easily be rebuilt during a siege.

The galleries for reverse fire, which may be considered as belonging to the same class, are certainly secure against an enemy's fire, but they are exposed to be destroyed by mining; and the destruction of a kaponier, or gallery for reverse fire, leaves a ditch without flank defence, whilst that from an earthen rampart cannot be silenced.

The reply to the above is that a reserve ought to be prepared, so that the garrison may be enabled to remount guns at any point, and especially to replace those in the kaponiers which may have been silenced: care must be taken to cover all the masonry from the fire of the besiegers; and, as the casemates may be built with *two* tiers of embrasures, even if some of the latter are ruined others will usually remain available for removing the guns to.

The objections against replacing outworks by independent advanced works are, that the available force is thus divided into several parts, and that the besiegers' Artillery has a great advantage when concentrated upon that defending small isolated works.

To these it may be replied that it cannot be admitted that Artillery scattered in isolated works has less effect against the besiegers' operations than if it were more concentrated, and that though those forts intended to check the besiegers' advance would not generally be armed with a great number of guns at first, they could be provided with them as the necessity arises, so as to take advantage of every favourable position and thus give elasticity to the defence, for which purpose communications which will be safe at all times must be constructed.

B. *As regards the Infantry, and the changes in the mode of employing them in the Attack of Fortresses.*—The before mentioned principle of employing open force more than formerly in sieges has naturally led to changes in the duties of Infantry.

Modern commanders have wished not merely to get possession of a fortress but also to take it *as quickly as possible*, in order that further proceedings might not be checked, or if they have, on the contrary, been obliged to blockade it, troops have been posted around it, supported merely by a few field works, instead of by long lines of circumvallation and contra-vallation, for extensive works have been considered as hindrances costing much time, men, and materials. If an attack by open force is found to be impossible or improper, the talent of the commander is required to be employed in finding out the decisive point against which to direct a *hurried* attack, and in carrying it out with energy: then, after the Artillery have performed their part, the Infantry are required to purchase with their blood the desired saving of time. To them is assigned the protection of the Artillery by means of good marksmen, the silencing of the defenders' Artillery, the defence of the works, forming lodgements by flying sap instead of by the regular sap, and the simultaneous storming of breaches and escalading of walls at points still intact.

Changes have also been made in the mode of employing infantry in the *defence* of fortresses. Most of the modern fortresses have been built with a view to one of the following cases. In one they are intended to form the points of support for extensive operations, so that armies could be collected under their protection preparatory either

* See Note at the end of this Paper.

to advancing or retreating; and in this case no siege operations would take place. In the other case the fortress is intended to be left to defend itself by means of the smallest possible garrison; and this is the one which we have to consider.

According to the spirit of modern tactics the Infantry, in defending a fortress, ought to remain firm on their posts in the work to be defended, and covered as much as possible, and should act on the offensive only in small detachments and when they have evident advantages in time and numbers; and their sallies should not be made from the fronts attacked, but from the collateral fronts, or from the gorge of the work attacked, so that the fire of the troops defending it may not be masked.

Hence it follows that garrisons no longer defend the covered way as they formerly did, by withdrawing from traverse to traverse, and disputing the possession of each intervening space, but when the besiegers reach the crest of the glacis they retreat to the guard-houses previously prepared in the re-entering places of arms, and allow the Artillery and Infantry in the works in rear to check the advancing enemy, whilst they occupy stoccades connected with the guard-houses, and hold themselves in readiness to advance, retreat, or await the arrival of supports.

In order to obtain a secure position from which Infantry can keep up a steady fire on the covered way and ditch, the revetted scarp has been replaced wherever it is possible by one with loopholed casemates in it, or by a revetment having above it an independent wall covering an open passage or chemin des rondes, from whence Infantry can fire through the wall by means of loopholes, or over the wall by means of banquettes; by this last arrangement the rampart is not exposed to assault even if the independent wall above the revetment is breached.

The principle of concentrating the force is also carried out in the defence of the main enclosure, for the ditch in every polygonal front is rendered impassable by building vertical walls to form its scarp and counterscarp, or by being filled with water, and it is swept by Artillery placed in a casemated kaponier: the ramparts are seldom occupied by large bodies of Infantry, but Artillery are spread along the whole line, as well as wall-pieces, which secure a long range and accuracy of fire, and yet require only one Infantry soldier to manage them.

The Infantry placed on the ramparts, in case of an assault being expected, are not employed in flanking the main ditch, but are intended for the direct defence of the parapet; for their support, reserves are placed in defensible barracks in their rear, or in empty Artillery store houses and other buildings capable of defence, from whence sallies may be made against the enemy if they penetrate into the ditch.

The defence of fortresses formerly ended with that of the breach in the body of the place; it is now prolonged by means of cuts formed across the rampart, and retrenchments in rear of it; and the construction of the latter is facilitated by the arrangement of the buildings inside, for in the best examples there are but few of these, excepting hospitals, which are not made defensible.

C. *As regards the Cavalry*, they can seldom be brought into play except during the first period of a siege, and nothing need be said about them except that free communications must be made for them wherever it is intended to employ them.

D. *As regards the Engineers*, the principles laid down above that the garrison should be concentrated for the close defence at the most commanding points, and that, for the distant defence, the Artillery should be placed with foresight, and so as even to give opportunities to them of making well arranged sorties, make it necessary for the modern Engineer to make himself acquainted with every phase of defensive warfare.

The general disposition of the works can only be determined on with reference to the form of the ground, the range of the weapons to be used, and with due consideration of the modes in which they can be employed. Similarity and systematizing should vanish—no work will be like another, for each should have its own particular physiognomy.

The ramparts will have, in some parts, broad communications and large spaces for mounting Artillery conveniently, and in others narrow terrepleins, so as to avoid giving an enemy room for cutting out lodgments in them.

The trace, profiling and loopholing of the walls must be such as to fulfil the object aimed at, and not to correspond to any particular *pattern.*

The strength of the works must vary, since some of the central points should be made capable of the longest resistance by employing all the resources of science, whilst the intermediate lines may be so weak that they can only resist a sudden rush, and must derive their protection from the collateral works.

The modern Engineer must however prepare good permanent means of resistance, so as to lessen the labour of forming and arming the works during a siege: the loopholed walls, kaponiers, permanent open batteries, traverses, retrenchment-walls, outworks, guard-houses, &c., being constructed beforehand, the garrison will be relieved from much tiring and dangerous work whilst besieged. He will also, in spite of all dangers, watch the movements of the enemy closely, and apply all the active and aggressive means which his art affords to the injury of the latter. This applies especially to the mining operations, (for which every preparation must be made during peace time), the counter-approaches, the daring sorties against the enemy's works, and the constant reconnoitring to discover the weak points of the enemy's works—in short modern fortification offers to the active and daring Engineer an extended field for usefulness.

E. *As regards Bombproof Cover.*—1. For the troops. It is generally impossible to provide bombproof cover for all, nor is it necessary: according to modern arrangements one-third remain under arms, one-third are kept ready at a moment's notice, and the remaining third should be allowed perfect repose.

Of the first portion only one half require bombproofs, since the other half are employed on duty on the ramparts, &c. The keeps and buildings forming interior retrenchments ought to afford accommodation for ⅙th of the garrison, so that at least ⅓rd of the whole garrison ought to have bombproof cover, the rest of the troops being kept in barracks or other buildings at a distance from the fronts attacked, and changes being made in the position of the troops so that none may suffer more than the rest.

2. For ammunition and stores. All the ammunition necessary must be provided with bombproof cover, and the provisions must at least be rendered secure against fire.

F. *As regards the Tactical Relations of Fortresses to the theatre of War.*—The tactical relations of fortresses are evidently the principal guides as to the changes required in the mode of fortifying: fortresses are no longer considered as objects for carrying on wars, but as the means of obtaining greater *results* from them, thus they can only exert an influence on the events of a war when they stand in connection with the armies in the field, and they ought therefore to afford support to the operations of the latter. They must not be scattered at equal distances apart through the country, as was common formerly, but must be placed in smaller numbers, and only at those points which have a strategic importance; and the strength of each should be greater than was formerly usual.

Note on the Resistance of Casemated Buildings against the Fire of Artillery.

Casemates having been generally introduced into most of the modern fortresses, both in the flanks of bastions and in kaponiers, (by which term is implied, not the earthen caponnières employed by the French, but the casemated buildings constructed for flank defence by the Germans and Russians), it is desirable that every opportunity should be taken to compare the amounts of resistance to breaching afforded by casemated works and revetted ramparts; and the capability of the former to resist *direct* fire was shewn by the experiments made at Bapaume in 1847, the report of which will be found at page 81 of the 1st number of the Corps Papers; but in order to test their power of resisting the effects of Artillery when *hidden from view* by earthen parapets, some practice has been lately carried on in Germany against a casemated guard-house constructed at the gorge of a small earthen work, its front face being 108 feet in rear of the parapet of the latter, and its cordon 3 feet below the crest of it. The wall exposed to be struck was 39 feet long, 15 feet high, and 5 feet thick, and it received support from two side walls 6 feet thick at right angles to its ends, and from a pier in rear of the centre about 4 feet square. It was pierced with 2 embrasures, 1 foot 9 inches wide at the neck, and 4 feet wide at the exterior. The arches over the casemates were 3 feet 6 inches thick, and the earth which covered a large part of their upper surface to a depth of 5 feet, rose 6 feet above the crest of the parapet in front, so as to be quite visible from the battery. The arches and lining of the embrasures were built of red brick, and the rest of the building was formed of clay-slate laid in excellent mortar.

Practice was carried on against this casemate with 25 Pr. iron howitzers (the diameter of which is 8·4 inches), from a point 530 yards distant and directly in front of it, using shells filled with lead and weighing 101 lbs., the charge being at first 2 lb. $10\frac{1}{2}$ oz., but afterwards 2 lb. 8 oz., and the angle of elevation being $6\frac{3}{4}°$ throughout.

The front wall was hit by 34 shells out of 112 fired during the first two days' practice, and the whole building was struck by 159 out of 400 fired during 4 days.

The result was that the front wall was much injured externally at the end of the second day's firing, yet the arches of the embrasures had not quite given way, and that at the end of the 4th day's firing the wall above the embrasures had fallen and blocked them up; yet the walls on each side of them, and the rubbish, still afforded some cover for musketry defence, and the building continued bomb-proof.

As it required 400 rounds thus to ruin a wall 39 feet long and 15 feet high, it may be calculated that it would require 4000 rounds to ruin the front wall of a building of two stories, like the main kaponiers in the German fortresses, under similar circumstances; but it is obvious that casemated flanks of *bastions* are much more exposed than kaponiers, as they cannot have covering works close in front of them, and batteries can be more easily placed on the prolongations of the ditches which they flank than on those of the ditches of the polygonal system, which usually fall on the collateral ravelins.

It may be useful to add that practice was also carried on against this building with a 50 Pr. mortar, the diameter of which was 10·3 inches. It was fired at 75° elevation from a distance of 500 yards, and 35 of the shells were filled with lead. The upper surface of the roof, the area of which was about 2,400 feet, was struck by 19 shells out of the total number fired, viz., 246; and none of these caused any serious injury even to that part of the arch not covered with earth.

Three shells were also placed in the holes made by those which had fallen on the building, and were loaded with charges of $5\frac{1}{4}$ lbs. each, but did little mischief by their explosion, either to the covered or uncovered portions. The holes produced by the fall of the shells in the earth were about $3\frac{1}{2}$ feet deep, and those in the uncovered masonry were 10 inches deep.

It must be observed that in these experiments the distance was exactly known, and that the effect of each shell was telegraphed to the battery; and it is obvious that considerable allowance must be made in calculating from them the effect of a battery worked under an enemy's fire, especially in cases where the casemated work to be silenced is entirely invisible from the battery, or has a protecting work *close* in front of it.—ED.

PAPER VI.

Reports on an Observatory formed of Scaling Ladders, Erected at the Royal Engineer Establishment at Chatham,

Under the Directions of COLONEL SANDHAM, R.E.

Mr. Stocqueler having proposed to the War Department an ingenious machine on wheels for elevating observers to a considerable height above the level of the ground, it was suggested that the object might be gained by the application of scaling ladders, an article of store in Field Engineer Equipment; and the following was the result of trials for the purpose.*

Report on the 1st Trial at the Royal Engineer Establishment, Chatham, July, 13th, 1857.

The observatory was constructed of the old pattern scaling ladders, which are 6 feet long, 22 inches wide at the top, and 26 inches at bottom, and weigh 34 lbs. Three sets of scaling ladders of six lengths each were used, the lengths being lashed together in the usual manner.

The ladders were laid out on a level piece of ground, so as to form 3 radii of a circle making angles of 120° with each other (see Fig. 1). Their upper ends were lashed together with the ordinary ladder-lashings attached to them, strengthened by a few feet of 1½″ rope.

The ladders were then raised by being lifted at the upper ends whilst the lower ends were moved inwards until the apex of the tripod had reached an elevation of 28 feet (see Fig. 2). A rope was then passed round the ladders at their lower extremities to obviate any danger of the feet slipping outwards.

In order to give stiffness to the structure, and to prevent any motion to an instrument that might be fixed at the top of the ladders, sap forks, 12 feet long, which were lashed to the rounds of the ladders with spun yarn, were used as struts.

Three 1½ inch planks were then placed across the 5th rounds from the tops of the ladders, to form a footing for an instrument and observer. The tripod was quite strong enough to support 3 men at the top at the same time.

The working party employed in the construction consisted of one non-commissioned officer (Sergeant Donald), and twelve Sappers.

14 fathoms of 1½ inch rope were used at the top and bottom in addition to the ordinary ladder-lashings.

The total weight of the structure was 5¼ cwt. The time required for putting together, lashing, and raising the ladders, would be about 20 minutes if all the necessary articles were on the spot.

The tripod was again erected on the 16th July, 1857, with the same scaling ladders and working party, for the inspection of Colonel Gordon, R.E., when an altitude of 29 feet was reached with perfect safety.

(Signed) { H. F. C. LEWIN, Lt. R.E.
M. LAMBERT, Lt. R.E.

(Signed) H. SANDHAM, Col. R.E., Director.

July 23rd, 1857.

* This application of ladders was suggested in the article on "Reconnoitring," in the Aide Memoire, see Vol. III, page 229, printed in 1852; and it may perhaps be useful in directing the fire of mortars placed where the object aimed at would otherwise be unseen.—Ed.

Report on the 2nd Trial at the Royal Engineer Establishment, Chatham, July 20th, 1857.

The scaling ladders used on this occasion were of Sir Charles Pasley's approved pattern of 1825. They are 12 feet in length, 18 inches wide at top, and 22 at bottom, and their weight is 66 lbs.

The observatory was formed of 3 sets of ladders of 4 lengths each. The ladders were laid out on a piece of ground so as to form 3 radii of a circle at angles of 120° with each other, that is, the lines joining the feet formed an equilateral triangle.

The upper ends were then lashed together with the ordinary ladder-lashings attached to them, strengthened by a few feet of 1½ inch rope (see *a,b*, Fig. 3).

The ladders were then raised by being lifted at the upper ends, whilst the lower ends were moved inwards, until the apex of the tripod had reached an elevation of 43 feet.

A rope was then passed round the ladders at their lower extremities (*c,d,e*, see Fig. 4), to obviate any danger of the feet slipping outwards. A few pegs or notches in the ground, in the absence of rope, would answer the same purpose. The ladders were also strengthened by sap forks 12 feet long, as struts, which were lashed to the rounds of the ladders with spun yarn.

Three 1½ inch planks were then placed across the 5th rounds from the top, to form a footing for an instrument and observer. The tripod supported three men at the same time, and was so stiff that an instrument placed upon it would be sufficiently steady for making observations.

The working party employed in the construction consisted of one non-commissioned officer (Sergeant Donald) and fifteen Sappers.

The total weight of the structure was 7¾ cwt. 15 fathoms of 1½″ rope were used, besides the ordinary ladder-lashings.

The time required for putting together, lashing, and raising the ladders, would be about 20 minutes, when all the necessary articles were on the spot.

(Signed) { H. F. C. LEWIN, Lt. R.E.
M. LAMBERT, Lt. R.E.

(Signed) H. SANDHAM, Col. R.E., Director.
July 22nd, 1857.

Appendix to the Report on the Observatory Erected at the Royal Engineer Establishment, Chatham, July 20th, 1857.

(1.) For the manner of putting together, and number of men, see Report on the observatory erected on the 20th of July 1857. The implements required for the construction are 1 knife and 1 handsaw. The time necessary before a man could ascend for ordinary observation is 20 minutes from the time the ladders are piled on the ground.

(2.) A platform was constructed of planks 10″ wide by 1½″ thick. These were sawn into the required shape and placed on the 5th rounds of each ladder (see Fig. 5). After the ladders were reared to the requisite height, and the planks were placed on the 5th rounds, the feet of the ladders were moved inwards about 12 inches, by which compression the platform and the whole structure was rendered much firmer. So firmly were the planks fixed that they could not be removed without moving out the ends of the ladders.

A series of angles were then taken without difficulty round the whole circle of the horizon with a theodolite, and proved perfectly correct. The platform and instrument were perfectly steady as long as no person was ascending or descending the ladders.

(3.) The wind on several occasions was fresh, yet it had no appreciable effect on the ladders, and observations could be taken from the top of them with the same accuracy as from any other high station exposed to the wind, as the top of a church tower for instance.

(4.) The weight of ladders, sap forks, &c., for the tripod of 12 lengths erected on the 20th July last was 7¾ cwt.

4 lengths of ladders, 46′ 6″ long, when joined together in the usual manner, at an angle of 70° with the ground, give a perpendicular height of 44 feet, when the base of the slope, i.e. the distance from the centre of the triangle to the foot of each ladder, is 15 feet; and the distance between the feet is 25½ feet.

3 lengths of ladders, 35′ 3″ long, when joined together in the usual manner at an angle of 70° with the ground, give a perpendicular height of 34 feet when the base of the slope is 10 feet and the distance between the feet is 17 feet. The weight of the tripod of 9 lengths, with the sap forks, &c., is 5⅝ cwt.

(5.) 70° seems to be the best inclination, and to give the best elevation. The distances of the points *c,d,e*, (Fig. 4) from one another would be, for a ladder tripod of 9 lengths, 17 feet, and for one of 12 lengths, 25½ feet.

(6.) A ladder tripod of 9 lengths of ladders was erected on the site of that of 12 lengths. The bottom lengths only of this tripod were removed and the remaining 9 were reared as before.

(7.) The tripod of 12 lengths, with the lashings and supports already described, stood without the least perceptible injury for the space of a fortnight, at the end of which time it was taken down. The platform answered perfectly all the required purposes.

(8.) The two photographs attached were taken, one whilst the observations with the theodolite were being carried on, the other when the tripod had been lowered nearly half-way, shewing the positions of the men employed.

(Signed) { H. F. C. LEWIN, Lt. R.E.
M. LAMBERT, Lt. R.E.

(Signed) H. SANDHAM, Col. R.E., Director.
August 11th, 1857.

OBSERVATORIES

FORMED OF

SCALING LADDERS.

FIG. 4.

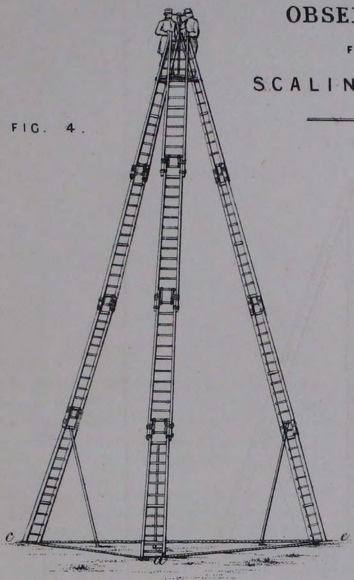


FIG. 2.

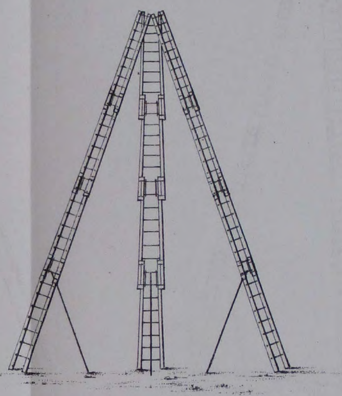
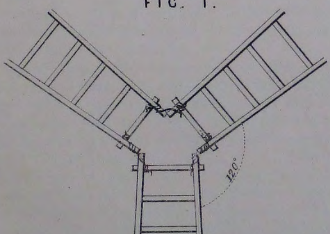


FIG. 3.

FIG. 1.



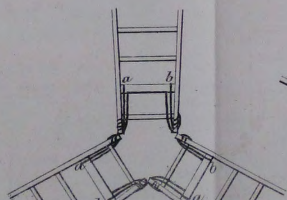
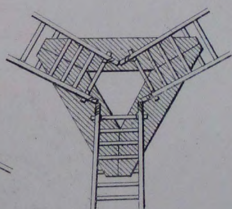


FIG. 5.



PLAN OF PLATFORM.

C. Moody, Lith. 257, Holborn, London.

PAPER VII.

On the Effect on Fortification of Recent Improvements in the Arms in Use,

By MAJOR EWART, Royal Engineers.

The changes in the art of fortification having ever been dependent upon, and rendered necessary by, alterations in the nature or power of the arms in use, it appears to be beyond dispute that the rapid strides which have recently been made in the improvement of infantry arms, as well as in the artillery service, must necessitate a reconsideration of those details which are part and parcel of the defensive system of the present day.

The disuse of bows and arrows, battering rams, testudos, balistœ, and such like elements of attacks, in favour of the employment of projectiles propelled by gunpowder, effected a complete revolution in the requirements for defence. *Now*, however, we have not to deal with new elements of attack and defence, but simply with improved means of effecting both the one and the other; hence, it is *modification* of present arrangements, rather than *revolution*, which has to be considered.

It is now proposed briefly to discuss these questions :—Which side in the conflict of attack and defence will be most benefited by the changes which have been alluded to ? What changes or modifications should be made in preparations for defence, as well of a permanent as of a temporary nature ? and, What will be the probable effect of such changes ?

As a prefatory step, it appears to be desirable to dwell briefly upon the nature of the improvements which have been recently effected, on those which are in progress, and those which are prospective.

The late war was commenced with troops accustomed to use an arm which shot but indifferently at 180 yards, and could not in the least be depended upon for longer ranges. Our rifle regiments could on an average make little better shooting at 300 yards, although here and there an old soldier, with Cape of Good Hope experience, might lay claim to be a *marksman* at the latter range.

On the eve of meeting the enemy, the Minié Rifle was put into the hands of the British troops ; but, inasmuch as they had not been trained to the use of a superior weapon, little advantage was gained in point of accuracy of fire, although it cannot be doubted that the random firing of long range missiles injured the enemy far more than would have been the case if the old smooth bore arms had been in use.

As the war advanced, the improved arm, known as the Enfield Rifle, took the place as well of Brown Bess as of the Minié, and became, before the peace, the uniform arm for the Infantry; but the want of proper training still prevented the establishment of such a superiority in rifle shooting as could materially affect the system of attack.

In the defence of Sebastopol, the Russians so much felt the want of marksmen that they selected a certain number of good shots from every regiment, armed them with rifles, and kept them solely for this duty. These marksmen were at their posts by day and upon moonlight nights, but upon dark nights the ordinary Infantry occupied their places.* These selected men by constant practice improved in the use of their arms, and from, at first, merely firing from caves, heaps of stones, or such like cover, they became by degrees those formidable occupants of pits and screens who so seriously impeded the progress of the attack, and, by their cat-like watch, lost no opportunity of picking off the passers along unfinished or damaged trenches.

The efficiency of these selected Riflemen would seem to be a proof (if proof were wanting) that the soldier improves the organ of vision as well as acquires the necessary steadiness of arm, and "knack" in firing, by care and constant practice.

Such a conclusion had already initiated in England that normal training establishment known as the School of Musketry at Hythe, where the gradual growth of a regular systematic training of eye and arm has fully demonstrated that accurate shooting can as surely be taught to the soldier as the mechanical motion of marching in step.

This establishment was so far in its infancy when the war commenced that it cannot be said to have effected much improvement whilst it continued, but at the present time the inoculation of the army by the introduction into regiments of officers and non-commissioned officers instructed at Hythe is so rapidly progressing that a great improvement in the rifle practice of the year is already apparent, and it may be assumed that, ere long, uniformly good average shooting may be reckoned upon throughout the service at a range of 600 yards, or double the distance at which the Riflemen of old were expected to make but indifferent shooting.

The annexed Return, which is published by permission of the Inspector General of Musketry, shews the results of practice made at 600 yards by a detachment composed of non-commissioned officers and men of different regiments (Line and Militia) none of whom had been under instruction for a longer period than six weeks.

Should the invention of Mr. Whitworth be found, upon further and more general trial, to be of the value anticipated by those who have carefully watched the first experiments, it appears probable that the range for accurate shooting may be still further increased, and that at least 800 yards will be the average distance at which the ordinary soldier, after reasonable training, may be reckoned upon as good for hitting his man.

Mr. Whitworth's principle of construction is also applicable to the improvement of arms throwing heavier balls, and therefore obtaining greater accuracy and longer ranges. The now almost obsolete wall-piece (clumsy and a "terrible kicker") may be replaced by a neat arm to be fired from the shoulder with little or no recoil, and good for ranges of from 1,200 to 1,400 yards at least. These would be invaluable as *special* arms for use in flanks, salients, or such like important points of defence.

Another very serious consideration presents itself in reviewing this march of improvement: it is the deeper penetration of the new rifle-bullets, and, great as is the difference between the old musket and the Enfield Rifle in this respect, the Whitworth bids fair to excel the Enfield quite as much as that arm surpassed the old musket.

* Ascertained from Russian officers after peace was proclaimed.

Return showing the results of Platoon Firing by a party of Soldiers at the School of Musketry, Hythe, on the 7th January, 1858, at 600 yards, against a Target 8 ft. 9 in. broad, in presence of General Sir J. Burgoyne, Bart., G.C.B., Inspector General of Fortifications.

Distance	No. of Men Firing.	No. of Rounds fired under the several circumstances	Detailed Statement of the Order in which the Firing was made.	Total Rounds fired in the practice recorded in the Diagram.	Total Hits in the practice recorded in the Diagram.		Per centage of Hits.		No. of Diagram recording performance.	Remarks.
						*		*		
Six Hundred Yards.	32	2	Marched to the practice ground in a column of sections; formed line to the left on the leading section, and fired two rounds by Sections, kneeling on coming into position, in volleys.	128	72	20	56	16	No. 1	* The numbers in this column shew the hits on a figure of a mounted soldier represented on the target *in profile*.
	32	2	Two rounds by Subdivisions in volleys kneeling, from right to left.							
	32	3	Three rounds as a Company in volleys kneeling.	384	217	71	57	18	No. 2	Cold Wind from left front; strong. Thermometer, 34°.
	32	4	File firing (standing), from left of Subdivisions.							
	32	2	Two rounds as a Company in volleys kneeling.							
	32	2	Moved to the right in a column of Subdivisions, and after changing direction returned to position, formed line to the right on the leading Subdivision, and fired two rounds by Subdivisions in volleys kneeling on coming into position. .							
	32	1	Moved to the right in a column of Sections, and after changing direction returned to position; formed line to the right on the leading Section and fired one round by Sections in volleys kneeling, on coming into position.							† Hits on figure of man and horse 23 Hits on rest of the target 43 Total hits .. 66
	32	3	Three rounds as a Company in volleys, kneeling. . . .	96	†66	23	69	24	No. 3	
			TOTALS.	608	355	114	58	19		

H

The results of some experiments on penetration made at Hythe are appended, but they are insufficient to enable any definite deductions to be drawn from them, and it appears desirable that this part of the subject should be practically entered upon in much the same way as was so completely done with the old musket at the Royal Engineer Establishment at Chatham.

TABLE OF EXPERIMENTS TO TEST PENETRATION AT HYTHE.

Date of Trial.	Description of Rifle.	Charge.		Distance	Object fired at.	Result.	REMARKS.
		Powder	Bullets				
Dec. 1853.	Enfield(1853)	2½ drs.	530 grs	100 yards	a butt of newly raised stiff clay.	Passed through 3ft. 3in.	
April 1855.	Do.	,,	,,	30 ,,	elm planks ½in. thick and ½in. apart, in frame	Passed through 11 planks	Entered 12th.
October 1855.	Do.	,,	,,	30 ,,	Do.	do.	do.
21st Apr. 1857.	Do.	,,	,,	30 ,,	Do.	Passed through 12	Indented 13th.
,,	Whitworth's	,,	,,	30 ,,	Do.	do. 32	Embedded in 33rd, through which it would most probably have passed had it not been arrested by the back of the penetration stand.

As regards the increased power of Artillery which may be reckoned upon for defensive arrangements, the result of improvement up to the present time appears to have been to increase the number of *heavy* guns to be allotted to a fortress, and to obtain better made guns than formerly. The Russian grape fire at the siege of Sebastopol, it may here be remarked, was certainly effective at double the range heretofore assigned to it.

It seems to be certain that the extension of the *range* of Artillery is now so necessary that it must sooner or later take place. The improvement of the bore of the piece, and of the mechanical construction of the projectiles to be fired, appears to be the most rational means by which so desirable an object can be attained.

By the use of the very heavy guns and mortars (as in the attack and defence of Sebastopol), which make so much better shooting than those of lighter calibre, the defence decidedly must benefit to the detriment of the attack, inasmuch as such large guns and mortars, with ample supplies of weighty ammunition, can seldom be available for the siege of any but a very accessible maritime fortress. It is to mechanical contrivance, and *not* to increased weight of metal, that such improvement of Artillery must be due as will give portable siege guns for breaching at long ranges with proper accuracy of fire.

It appears to be evident that the art of fortification will be affected by the change from muskets to rifles, as general Infantry arms, in the following particulars:

1. Length of lines of defence and consequent diminution of the number of points of attack.

2. Cost of works.

3. Command of ground in front of works.

4. Thickness of parapet.

(1). It being one of the first principles in fortification that the lengths of lines of defence should be regulated by the power of the arms likely to be used in the flanks, it appears to be beyond doubt that the lengthening of such lines must result from the increase of range which has been secured for the ordinary arm of the soldier of the Line, as well as for the grape fire of the Artillery, leaving out of the question the possibility of the adaptation to such purposes of those *special* arms* to which allusion has been made above.

The Engineer would seem to have much cause for rejoicing in this power of lengthening his lines of defence, inasmuch as the formerly assigned limits necessitated such frequency of salient points that the extent of works to defend a place was broken up into a great number of "Fronts of Fortification," and each salient angle being a point of attack, the besieger derived advantage from that frequent occurrence of them which resulted from the fronts being of such limited extent. Now inasmuch as it has been shewn that the range of the Infantry soldier's weapon has been at least doubled, and as the Russian grape fire in the defence of Sebastopol was quite effective at upwards of 600 yards, it certainly appears that lines of defence may now be extended from 300 yards to 600 yards; that fronts of fortification may thereby be made much longer, and consequently that the "points of attack" will be diminished in number †

(2). As bastions will be more distant in consequence of the lengthening of lines of defence, they will be required to be larger, and the theoretical trace of the ravelin will need adaptation to the new system, but notwithstanding these extensions or alterations, the increase in length of the fronts of fortification (as above proposed) will certainly have the effect of diminishing the cost of works of defence on a large scale, for *to cover the same ground* with works fewer breaks will be necessary, and consequently there will be a diminished number of running yards of high and costly revetments.

(3). It being a requirement in defensive arrangements that the enemy shall be brought *under fire* as soon as possible, and the creation of obstacles in advance of works being with the view of *detaining him under fire* as long as possible, it is clear that the more than trebling of the effective range of the infantry soldiers' arms must have the effect of materially aiding the defence at the cost of the attack; but it is also clear that the "tables will be turned" unless houses, gardens, vineyards, or such-like cover, are kept at a much greater distance from the walls of a place than was formerly deemed necessary.

(4). The greater penetration of the bullets of a conical shape, which are shot from a rifled bore, than that of the round balls from a smooth bore, must induce a reconsideration of the thicknesses which have heretofore been deemed sufficient to protect a man firing from behind cover, whether it be of earth, wood, iron, or other materials.

* And probably also of breech-loading arms which will no doubt come into use for *special* purposes, giving, as they do, great rapidity of fire.

† It must not be forgotten that the lengths of lines of defence must depend principally upon the the range of grape and canister, since more than 250 balls may be fired at once from a gun of 8 inches diameter, whilst not more than 12 riflemen in double rank can fire from the space which it occupies; and also that the ground will seldom admit of every portion of a ditch 600 yards long being *in oneplane*, so as to be capable of being defended by a bomb proof work.—Ed.

It will only be by careful experiments that the details of such thicknesses can be arrived at, and it appears to be only necessary now to point to the fact that *alteration will* be required.

Looking to the results of the few experiments on penetration yet tried with the Whitworth rifle, it seems to be almost certain that if this arm be hereafter adopted such power will be given to the defence that an entirely new system of attack must be introduced. Close advance, according to all preconceived notions, will be rendered most difficult, if not altogether impossible. The sap rollers and mantlets, now considered to be so essential for sapping, will, if constructed as at present, be useless; and it seems scarcely possible to substitute for them other like cover, which, being sufficiently portable, will be proof against the deeply penetrating bullets of the Whitworth rifle.

The tactics of the attack will doubtless be adapted to the greater power which has been shewn to have been, *or is likely to be*, secured for the defence; but from what has been said it is thought that it will be evident that, as yet, the gain has been decidedly in favour of the defence, to the detriment of the attack.

The case which has now been considered has been the effect of the improvement of arms upon permanent fortification; but as the requirements and arrangements of those defensive works which are thrown up in the field are dependent upon the same principles, although more hastily and less carefully carried out, it is scarcely necessary to say much respecting the effect which these improvements will have upon the construction of field works.

The Engineer engaged in the defence will, in such a case, also derive great advantage from the increased range of the arms in use, and especially of small arms, for, how often in arranging a system of detached works, or laying out lines of intrenchments, has he been compelled, by the limits of his lines of defence, to place flanking works where the ground is not favourable! His defences can now be arranged so as to afford mutual support within a compass of double the extent which could formerly be embraced, and those who have reconnoitred ground with a view to its occupation by detached field works will readily and fully appreciate the advantages to which allusion has been made. It will also be remarked that, as guns of large calibre are very seldom available for the defence of field fortifications, the recent improvement of small arms will contribute more to the power of fighting such works than to the defence of those of a more permanent character, in which Artillery must ever play a most conspicuous part.

C. B. EWART, Capt. R.E. and Major.

25th January, 1858.

PAPER VIII.

Reports on Hutting made by the Board of Officers assembled in the Crimea, and Observations and Suggestions on the Subject, by CAPT. BINNEY, Royal Engineers.

Report of the Board of Officers.

1. In obedience to the General Orders of the 20th of February, 1856, the Board of Officers therein named, viz.:

Lieutenant-Colonel Hallewell, Assistant Quartermaster-General;
Major Montagu, Royal Engineers;
Major Newton, Royal Artillery;
Major Eagar, 81st Regiment;
Staff-Surgeon Paynter;

have assembled on various occasions, for the purpose of examining the different descriptions of hutting in use by the English, French, and Sardinian armies, in the neighbourhood of Sebastopol.

2. The first camps visited were those of the English, where the different modes of constructing stables, cook-houses, &c., were carefully observed, and the opinions of general, commanding, and other officers ascertained, as to the way in which the different patterns of Government huts had answered the purposes for which they were intended. After a careful consideration of these opinions, and from personal observation, the Board has drawn up the following report.

On Soldiers' Huts.

3. The large-sized panel double huts are roomy and warm, and, having felt on the roofs, between the boards, are waterproof, excepting at the joints, where, if they be not very accurately fitted, the wet and wind penetrate. They are easily put up when the different parts are on the ground, and, being fastened with screws and nuts, are intended, if required, to be taken to pieces and removed to other positions. They are heavy, and the different pieces cannot be carried conveniently on pack-horses, and unless very carefully packed and numbered, much delay takes place in sorting and in erecting the huts. In many cases, owing to their being badly fitted, it has been necessary to use nails in erecting these huts, which was never intended. Their great length frequently causes considerable straining at the joints, and there is generally more difficulty with the ground, so as to secure a good foundation.

4. From what they have seen of these huts, the members of the Board are of opinion that many of those now in use in this army would not stand being taken down, transshipped, and re-erected. The large single panel hut, the same size as the above, is very inferior; being single boarded, it is lighter to transport, but it requires a covering of felt, or other material, to make it weather proof.

5. The small double boarded panel hut is certainly more serviceable than the large one, as, from its reduced length, there is less strain at the joints, and less difficulties present themselves in securing a good foundation for it.

6. The small single boarded panel hut of course possesses the chief disadvantages of the large one, being far from weather proof.

7. The Portsmouth small hut, of the pattern first issued, with feather-edged boards, is easily transported, and can be moved bodily for short distances. It is also easily ventilated, but it will not bear being taken to pieces and transhipped without great loss; and, being single boarded, must be completely covered with felt or other material to be rendered weather-proof.

8. The small Gloucester hut appears to be the most simple and the easiest transported; there is less difficulty in issuing it to the troops, and any deficiencies are easily made good, while any surplus pieces can be always turned to a useful purpose, and it can, like the Portsmouth hut, be bodily moved short distances. The boards are the same thickness throughout, which renders them less liable to crack when nailed on; but being single, it also requires a covering of felt, or some other material.

9. This hut appears to be the most serviceable of all those issued by Government. The more recent pattern of the hut has higher sides, and a greater pitch to the roof. The arrangement, in the last three huts, of guard beds, and a pitched path of stones up the centre, is decidedly good, and conducive to cleanliness. (For details see Pl. 1, and Appendix.)

10. The hut known by the name of the Paxton hut, and in use in the Army Works Corps, is, in consequence of being double, with felt between, perfectly waterproof; it is, however, very heavy, a large quantity of material is used in its construction, and it is not a hut calculated for military purposes.

11. A strong opinion exists in the army that it would have been better to have given plenty of boards, nails, scantling, tarpaulin, and tools to the troops, and have made them hut themselves.

12. One objection to this course is that probably a large quantity of material would have been wasted from want of skilled labour.

13. The Gloucester hut is the nearest approach to the giving of merely planks, nails, and scantling.

14. The French troops are hardly any of them in wooden barracks. All their wooden huts are constructed on the same principle as the Gloucester huts, with this exception, that in many instances, instead of using fillets where the boards meet, the boards are put on about one-third of their width apart, and these openings are covered with boards the same width as those first fastened on, but many have much more extended eaves than ours, which is an advantage, and the walls are much lower. They average about the same size as our small Gloucester hut, and almost all their huts have got a double angle-tie, which must add much to their strength.

15. The huts constructed by the Sardinian army are without doubt the nearest approach to what huts should be for an army in the field.

They have depended entirely on the means they found at hand, and the whole of that army is comfortably and economically hutted. Of course their position enabled them to effect this, which ours did not.

16. Before they commenced hutting, a Board of Staff Officers was employed to consider the matter, and decide on the best means to be adopted.

A plan was decided on which has been exactly followed throughout their army. Their huts are on the same principle as those made in Bulgaria. They are dug out about three feet; the roof, which is made of wattling or brushwood, on rough rafters, coming down to the ground, is covered with sundry coatings of mud, in which is mixed a small quantity of refuse chopped straw or hay. Each hut is calculated to hold six Infantry soldiers, or four Cavalry, the latter having their horse appointments with them in the hut. Each hut has its fire-place, and is quite warm and weather-proof. (See Plate 2.)

17. No signs of damp were observed in them. Of course on certain ground slight alterations in the plan had to be made; as, for instance, where the ground was very rocky, instead of excavating, stone walls were built, and the roofs placed on them.

18. The Board observed nothing in the kitchens of the French and Sardinians worthy of remark, except the hospital kitchens of the latter, which are very complete. The boilers in them had been sent from Genoa, as also had the bricks. On the contrary, the kitchens in the English camps are most of them of a very superior construction, and many would be more in place in an English barrack square than in the field. Many of these kitchens have regular boilers (brought out of Sebastopol), which in many cases have been skilfully fitted for use, with the assistance both of bricks made by the men themselves, as well as of a considerable number of Stourbridge bricks found in Sebastopol.

19. Those best adapted, however, to an army circumstanced as this one is, are simple fire-places or flues, made with stone or bricks, the grate being composed of pieces of hoop-iron, which have come off barrels, trusses of hay, &c., and on which the common camp-kettle can be placed. The system of flues, with openings for the camp-kettles, lessens the consumption of fuel.

20. The new pattern stove, issued this winter with the hutting, is also available for cooking purposes; and by cooking in the huts, either in fire-places or in stoves, a great saving in fuel is obtained.

On Artillery and Cavalry Stables.

21. The advantages of the Government Stable hut are few compared with its disadvantages. Though sufficiently weather-proof, it is with difficulty transported, and it holds comparatively few horses. In almost all cases these stables have been improved by alteration made in the course of erection. As issued, the sides are easily pushed out by the horses' heads, which renders it necessary to build up walls of masonry or mud against them, or to place hoop-iron bands from upright to upright in the interior. There is no place to keep the harness or horse appointments.

The French Emperor's stable is very easily constructed, very light, and sufficiently weather-proof, but in exposed situations the canvass, from the distance between the points where it is fastened to the frame-work, is very liable to split and tear during high winds. There is no place for the harness, &c.

22. Most of the Land Transport stables have been constructed by the officers commanding the different battalions, with common materials, on their own plans. Some of them are very simple, and at the same time perfectly answer the purpose required. Much of the material used in these stables was obtained from Sebastopol, as indeed was much of that used by the Artillery in the reconstruction of the Government stables.

23. The French stables are generally simple sheds, having walls formed of mud and dung.

There are some stables, however, in the French Siege Train on a large scale, and most substantially built; they are over 30 feet wide, and have a low wall 3 feet high, and a manger running up the centre.

The planking is very substantial, and a shelf extends the whole length of the stable, attached to the interior of the wall (which is of wood) and on which are placed the harness, horse furniture, &c., each harness behind the horse to which it belongs, which is a very desirable arrangement.

24. The Sardinian stables are simple and serviceable. The assistance they have received in the construction of them has been in scantling and planks for the formation of roofs. The walls are generally composed of mud and litter; the inside being supp rted with wattle or brushwood. (See Fig. 5, Pl. 2.)

25. For stables, therefore, it appears that merely giving plenty of materials, tools, &c., would be the simplest and quickest way of covering the horses, placing them in one line if the stable be constructed on sloping ground, and in a double line, head to head, when on level ground.

26. Sufficient scantling, and boarding, three-quarters of an inch thick, would be required to construct the roof, the boards being placed horizontally and overlapping. Hooks or pegs should be fastened the whole length of the stable for the horse appointments, and the walls should be constructed of mud and litter, which could slope outwards at an angle, the inside being supported either by brushwood or the staves of old casks.

These walls are quickly constructed, and in warm weather, when they are not required, they are easily removed.

It is considered that a roof constructed as above would be sufficiently weatherproof without canvass.

On Hospitals.

27. Every pattern of the Government hutting has been used in our hospitals. That which appears to have answered by far the best in every respect is the large double boarded hospital hut (the first regular hospital hut issued to the army) for twenty-four patients. The advantage of its having the footing raised is of much consequence to the sick; but it is considered that a few additions and slight alterations should be made in this hut. (See Pl. 3.)

28. The porch at one end should remain as at present, but with entrance direct, so that a wounded man when carried in might not be shaken or jolted, as would be the case if the porch had a door at its side; and with regard to the other porch, it is recommended that, instead of a surgery or store being there, there should be two privies substituted, and also a space for keeping the scrubbing brushes, brooms, &c., for cleaning the hospital.

29. The privies should be made in the manner usual in common privies, excepting that a large tub should be placed in each, to receive the soil, &c., which tubs could be removed when necessary from the outside of the building, by having a door with hinges to rise and fall. By such means all offensive smells would be avoided.

30. There would be a door separating this porch from the ward, and the outer door should be placed at the side of this porch, as by this means more light and air would be obtained for cleaning, &c.

31. The ventilators at the top of the hospital hut should be much larger, and made so as not to admit rain, snow, &c. The roof or eaves should project at least one foot and a half, so as to carry off the wet free from the building.

32. The windows might be a little larger, and some ventilators may be made in the walls, level with the floor, to open and shut.

33. Some better arrangements should also be made with regard to the stove-piping, which at present is not safe, instances having occurred of the roof taking fire from the heat of the pipe. Each piece of pipe should have a shoulder to prevent one slipping over the other. A damper would be useful in hospital stoves.

34. With respect to the number of patients which a hut of this description is calculated to accommodate, it is probably questionable whether 600 cubic feet is an ample allowance of air for a sick man.

35. The Board recommends that there should also be smaller huts for twelve patients, on the same plan as the one above spoken of.

36. A small hospital hut should also be available for other purposes, half the hut being divided off from the other part for an operating room, with a large window, as plenty of light is here absolutely necessary.

37. With regard to hospital kitchens, the boiler and hospital cooking stove, containing oven, &c., as used at the Sanatorium at Balaklava, appears sufficient for a field hospital, with the other means which have been usually employed.

38. In the French hospitals the Board saw little worthy of observation.

39. The Sardinian hospitals were very similar to those of the English army: the only difference in one ward was, that a framework ran along the centre of the ward for its whole length, forming a species of tables and shelves for the patients to keep a few personal comforts, and to place their cups, plates, &c., on, whilst taking nourishment. A row of beds ran along each side of the framework, the patients' heads being towards the middle of the ward, leaving the sides free, instead of the centre of the ward.

The Sardinian medical officers approved of this plan, stating that it obviated the chance of damp and draughts of air, which might penetrate the sides of the building, acting deleteriously to patients whose heads were placed in the usual manner along the building.

Concluding Remarks.

40. The felt issued in the army has by no means answered the purpose required of it. Tarpaulin or canvass, with a supply of prepared tar, although perhaps more expensive at first, would be more economical in the end, much more serviceable, more convenient for transport—can easily be removed or repaired if necessary, and used afterwards for covering stores and other purposes. Coarse calico has also been recommended instead of felt.

41. If huts are to be supplied to officers, the most convenient pattern appears to be the new small Gloucester hut, which can be divided into as many compartments as may be required.

42. In the event of material being given for hutting purposes, a supply of doors, hinges, and windows of an uniform pattern should be supplied.

43. The Board has received a Paper on Hutting from Messrs. Wakefield and Bailey of the Commissariat, which, as it contains some useful information on the subject, is annexed to the report.

(Signed) H. MONTAGU, Br. Major, Royal Engineers.
ROBERT EAGAR, Major 31st Regiment.
H. P. NEWTON, Br. Major, Captain Royal Artillery.
JOSHUA PAYNTER, 1st Staff Surgeon.

Memorandum on Soldiers' Hut, 30 by 18 Feet.

(Shewn in Fig. 6, Pl. 2.)

This hut is on the same principle as the Gloucester hut. The walls are made low, as on most ground the floors can be sunk* or the walls built of stone. One gable should, if possible, be built of stone, so as to admit of a chimney with a fire-place sufficiently large to hold the camp-kettles of the squad. The arms and accoutrements should be ranged along the gable wall. The path up the centre to be pitched with stone, and the guard-beds to be placed so that they can easily be taken up. When the ground admits of it, two huts can be joined together, in which case the stone gable and chimney can be common to both. The planks for the walls should be issued twelve feet long, and not cut till they are on the ground, so that if stone is used they can be made available for other purposes.

W. HALLEWELL, Lieutenant-Colonel,
Assistant Quartermaster-General.

Sebastopol, 22nd March, 1856.

* The dotted lines, *a b*, in Fig. 6, Plate 2, shew the space which may be excavated where the ground admits of it and proper drainage can be secured.—Ed.

Paper on Hutting, by Messrs. Wakefield and Bailey.

The materials for constructing a hut should consist of scantling of two sizes; the first 2 by 3½ inches thick, and 16 feet long; the other 1½ by 3 inches thick, and 11 feet long. The first should be for sleepers, wall-plates, uprights, and joists, such scantling would answer, in two lengths, for a hut 32 feet long, and in one length for the breadth. One length cut in halves would make two uprights, allowing the wall-plates of the hut to be eight feet from the sleeper. The scantling for the rafters is the requisite length for a hut 16 feet wide, so as to give the roof a good pitch.

The sides should be boarded with ¾-inch deal plank, in 16 feet lengths, and 11 inches wide. Thus, allowing 1½-inch lap, there would be sixty boards to a hut. The roof should be covered close with ½-inch deal plank, also 16 feet long and 11 inches wide. Each roof would therefore require forty-eight boards, and six for the gables.

The coarsest description of strong calico, two yards wide, and well tarred, would effectually exclude the rain. The doors and windows should be sent out ready made.

The scantling and ¾-inch boards would do for making a camp-bed the whole length of the hut.

2-inch nails for the roof and 2½ inch for the sides, with clout nails for the canvass, would be most efficient.

The reasons for our coming to this determination are as follows:—

The ordinary huts sent out in panels pack badly on board ship, by which a great deal of the stowage is lost. Boards and scantling would pack perfectly close, and no space would be lost.

If any portion of a ready made hut be lost or damaged, it is difficult to replace; whilst, with boards and scantling, huts can be made of the most convenient size to suit circumstances.

The present huts, being all over half-inch boards doubled, are much heavier than requisite. The ordinary felt is heavy, liable to damage, and very seldom renders the roof watertight; whereas the calico would be light, readily applied, and much more effectual in excluding rain.

From experience we have found that the ordinary skilled labour in a regiment would, with little guidance, put up a hut of scantling and boards in less time than one of the prepared huts, and there can be no question of the boards and scantling being carried, either in carts or on men's shoulders, much more economically than the framed panels.

(Signed) W. BAILEY, Assistant Adjutant-General.
F. WAKEFIELD, Commissariat Works Corps.

APPENDIX.

Directions for Erecting a Soldier's Hut of the Gloucester Pattern.

Prepare and level the ground 28 feet long by 16 feet wide, the size of the building, and as much as possible provide small stones, gravel, or ballast, 6 inches or a foot deep, for the sills to rest upon.

Unhoop the packages and keep the pieces composing each together, with the letter mark exposed to view, for reference.

D Package contains the two end sills.

C The four side sills: one, 14 feet 3 inches sill, and one 14 feet sill, for each side. Place these on the ground perfectly level, nail and secure the lap down, running a line or string along the outside to keep the side sills straight, and measuring from corner to corner to keep the frame perfectly square.

I and G contain the posts. Fix them all in the sills and drive them home, distinguishing the four angle posts and the four door posts with the notches inside for the transoms to run into.

C and D contain all the wall plates. Lay them on the posts and drive home one of 14 feet 3 inches and one of 14 feet to each side.

D Contains the end transoms.

H Contains the side transoms. Drive them all home flush with the outside.

N.B. – It would now be desirable to keep together in place the angles of the hut by temporary braces, using a roof or side-board.

F Contains the rafters of the roof. Put them together on the floor, nailing on the collars and upright hanging pieces in the centre, and lay the five roof frames upon each other to preserve exactly the same span in each.

Get the exact span, measuring upon the floor from sill to sill across the hut, then fix on and nail down the roof. In erecting the roof, brace each roof rafter to the sills by the roof boards.

N.B.—The roof boards are made to project over the sides and windows about 4 inches, but if it be wished, in situations not much exposed to wind, to give a greater projection or overlay, cut upon the floor the 5 rafters 3 or 4 inches shorter, as shewn upon the plan, X and Y, in the direction of the dotted lines, taking care to cut equal lengths off each rafter: the roof boards will then project farther out at the eaves, and the roof itself be a little lower.

L, M, and N contain the side boards. Nail them on against the sills, transoms, and plates, keeping the tops well within the plates, so as not to prevent the roof boards being nailed against them. Put on the fillets over each joint of the side boards, nailing them well down.

The windows should not be fixed, and are intended to run outside upon the window fillets nailed against the boarding, and through into the transoms, and one fillet also for the top of the window, nailing against each window fillet a smaller one to form a top and bottom groove for the window to run into, thus ▙

E Contains purlins: place them on the roof and nail them to the rafters.

C and E contain the two ridge pieces: lay them on the roof and nail down.

J and K contain the roof boards: nail them on, keeping the top ends clear against each other, and commencing from one of the ends of the hut, allowing a projection or overlap of about 4 inches at each end of the hut.

Put on the ridge cap, and then nail down the roof fillets over each joint of the roof boards. One roof board in each of the compartments must have 4 or 6 inches sawn off, where the ventilator board must be placed and nailed only at the top, so that it may be raised to give more air if required.

O Contains the end boards; commence from the door post, leaving half an inch clear space inside of each door post for the door to shut against.

A and B contain the soldiers' bed sleepers; fix them in the notches on the sills, nailing the 14 feet 6 inch by $1\frac{1}{2}$ inch sleeper against the posts on top of sill, the 7 inch by $2\frac{1}{2}$ inch in the middle, and the 5 inch by $2\frac{1}{2}$ inch in front; then nail the boarding, and afterwards place the footboard $2\frac{1}{2}$ inch by 2 inch on the top of it.

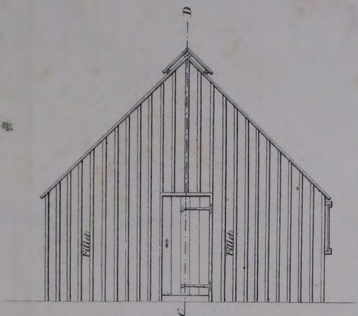
Number and Contents of Packages for each Gloucester Hut.

Package	Contents	Feet.	In.		In.		In.
A	2 Bed Sleepers.	14	6	×	7	×	$2\frac{1}{2}$
	2 do. do.	14	6	×	5	×	$2\frac{1}{2}$
	4 do. do.	14	0	×	6	×	$1\frac{3}{4}$
B	2 do. do.	14	0	×	7	×	$2\frac{1}{2}$
	2 do. do.	14	0	×	5	×	$2\frac{1}{2}$
	4 Foot Boards	14	0	×	$2\frac{1}{2}$	×	2
C	2 Sills.	14	3	×	3	×	3
	2 Plates	14	3				
	2 do.	14	0				
	2 Sills.	14	0				
	1 Ridge.	14	0				
D	8 Window Fillets or Runners outside.	4	6	×	$1\frac{1}{2}$	×	1
	2 Sills.	16	0	×	3	×	3
	2 Plates.	16	0				
	4 Shelves.	16	0	×	9	×	1
	3 Collars.	13	0	×	$4\frac{1}{2}$	×	$1\frac{1}{2}$
	4 End Transoms.	6	6	×	3	×	2
E	8 Purlins.	14	0	×	3	×	3
	1 Ridge.						
F	10 Rafters.	12	0	×	3	×	3
	3 Ridge Caps.	9	6	×	3	×	2
G	12 Posts.	6	0	×	3	×	3
H	8 Side Transoms.	7	0	×	3	×	2
	8 Fillets.	7	0	×	$1\frac{1}{2}$	×	$0\frac{1}{2}$
	5 Collars.	7	0	×	3	×	2
	3 Hangers.	7	0	×	3	×	$1\frac{1}{2}$
I	2 Posts.	6	0	×	3	×	3
	2 Doors.	5	7	×	2′ 7′	×	$0\frac{3}{4}$
	2 Windows.	2	8	×	2′ 2′	×	$1\frac{1}{2}$
J(4 of these)	14 Roof Boards.	12	0	×	8	×	$0\frac{3}{4}$
	14 Strips.	12	0	×	2	×	$0\frac{3}{8}$
K(2 of these)	15 Roof Boards.	12	0	×	8	×	$0\frac{3}{4}$
	15 Strips.	12	0	×	2	×	$0\frac{3}{8}$
L(3 of these)	14 Side Boards.	6	0	×	8	×	$0\frac{3}{4}$
	14 Slips.	6	0	×	2	×	$0\frac{3}{8}$
M(2 of these)	15 Boards.	6	0	×	8	×	$0\frac{3}{4}$
	15 Strips.	6	0	×	2	×	$0\frac{3}{8}$
N	12 Boards.	3	3	×	8	×	$0\frac{3}{4}$
	12 Strips.	3	3	×	2	×	$0\frac{3}{8}$
O(2 of these)	1 End Package.						
	24 Boards and 24 Strips.						
P (5 of these)	12 Floor Boards.	6	0	×	11	×	1
	8 Ventilators and Fillets	0	16	×	11	×	1

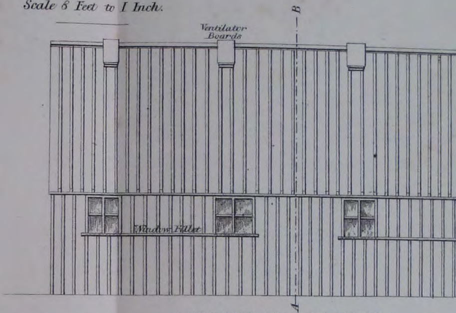
One Box containing Hinges, Lock, Bolt, 1 Hammer, 1 Gimlet, Nails, Screws, Screw driver, and Lithograph of Hut.

THE GLOUCESTER
SOLDIERS' HUT.

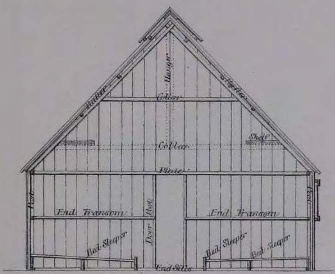
Scale 8 Feet to 1 Inch.



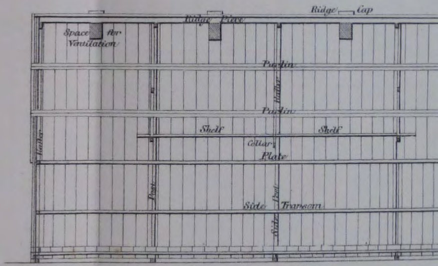
END ELEVATION.



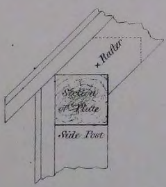
LONGITUDINAL ELEVATION.

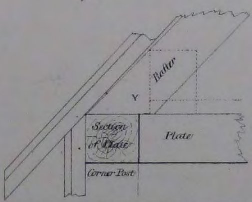


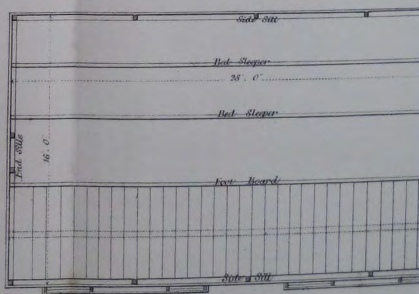
TRANSVERSE SECTION THRO' *C. D.*



LONGITUDINAL SECTION THRO' *C D.*







PLAN.

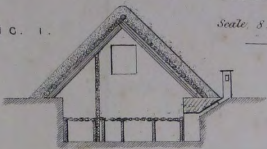
SOLDIERS HUT

CONSTRUCTED BY THE

SARDINIAN ARMY IN THE CRIMEA.

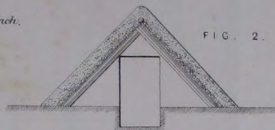
Scale 8 Feet -1 Inch.

FIG. 1.



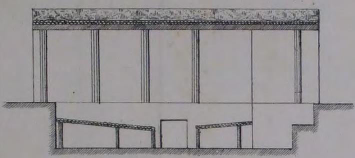
SECTION ON A.B.C.D.

FIG. 2.



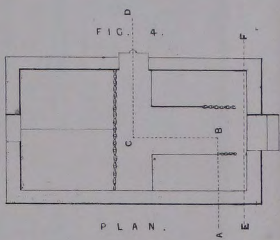
SECTION ON E. F.

FIG. 3.



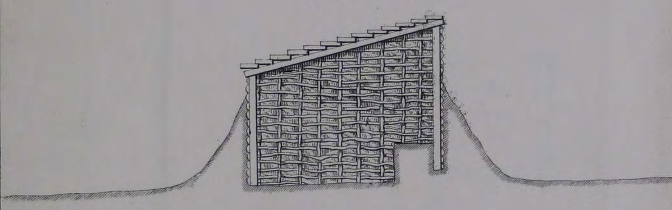
LONGITUDINAL SECTION.

FIG. 4.



PLAN.

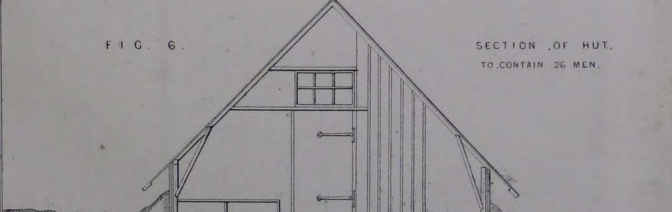
FIG. 5.



SECTION OF SARDINIAN STABLE.

FIG. 6.

SECTION OF HUT, TO CONTAIN 26 MEN.



Section through Walls & Gable.

Scale of 2 Feet to an Inch

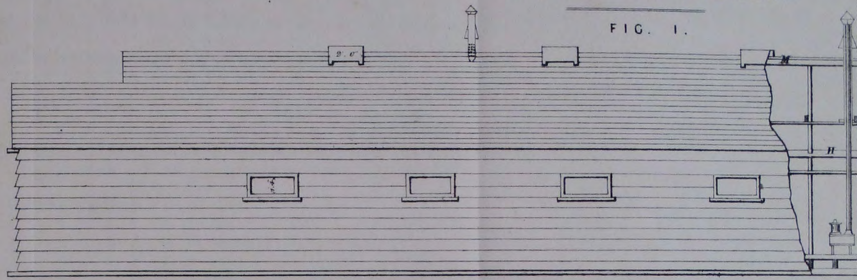
C. Moody Lith. 257, Holborn, London.

HOSPITAL HUT

FOR 24 PATIENTS

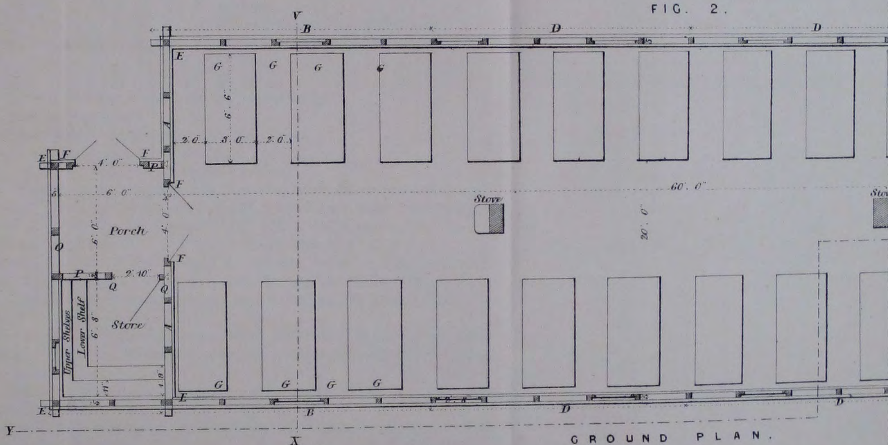
USED IN THE CRIMEA.

FIG. 1.



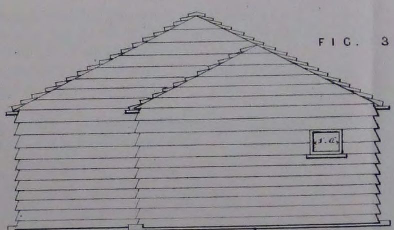
ELEVATION & SECTION ON LINE Y. Z.

FIG. 2.



GROUND PLAN.

FIG. 3.



END ELEVATION.

Scale 8 Feet - 1 Inch.

FIG. 4

List of Materials for one Hospital Hut.

8 Plates and Sills $4\frac{1}{2}'' \times 3''$ for Sills of Building 16 feet long with halving for end plates.

8 Plates and Sills $4\frac{1}{2} \times 3$ for Sides 15′ 6″ long, for intermediate do.

4 do. do. $4\frac{1}{2} \times 3$ for Ends 22 feet long.

2 do. do. $4\frac{1}{2} \times 3$ for Porches and Store 14′ 8″ long.

10 do. do. $4\frac{1}{2} \times 3$ for do. do. from 7′ 9″ to 8 feet long.

17 Posts 4×4, 7 feet long : 8 for Door Posts have a fillet $2'' \times 1''$ nailed on one edge to form rebate for Door.

57 Posts 4×2, 7 feet long, 2 for Door Posts to Store with fillet as above.

4 Uprights in Gables $4 \times 2 \times$ 1′ 6″ long.

4 do. $4 \times 2 \times$ 2′ 11″ long.

4 do. $4 \times 2 \times$ 4′ 2″ long.

42 Rafters $4\frac{1}{2} \times 2 \times$ 12′ 0″ long.

21 Collars $4\frac{1}{2} \times 2 \times$ 14′ 0″ long.

5 Ridges $4\frac{1}{2} \times 1\frac{1}{2} \times$ 13′ 0″ long.

9 Rafters $4\frac{1}{2} \times 2 \times$ 8′ 0″ long. for Porches and Stores.

1 Ridge piece $4\frac{1}{2} \times 1\frac{1}{2} \times$ 6′ 6″ long.

8 Braces $4 \times 2 \times$ 5′ 4″ long for Angles of Buildings.

5 Sleepers $4\frac{1}{2} \times 3 \times$ 12′ 0″ under Centre of Joists.

43 Joists $7 \times 2\frac{1}{2} \times$ 21′ 0″ long.

16 do. $7 \times 2\frac{1}{2} \times$ 6′ 6″ long.

1441 prepared Floor Boards 9 inches wide and 13 feet long.

4 Zinc Covers to Ventilators.

1 Bundle containing 16 Blocks to support Ventilators.

12 Squares rough plate glass 2′ 5″ × 1′ $4\frac{3}{4}$″.

1 do. do. do. 1 foot square for store.

12 sets for Windows containing 96 pieces thus distributed, for one outer frame—
2 pieces 2′ 10″ × $5\frac{1}{2}$″, and 2 pieces 1′ $7\frac{3}{4}$″ × $5\frac{1}{2}$″ for one inner frame for glass.
2 pieces 2′ $7\frac{3}{4}$″ × 2″, and 2 pieces 1′ $7\frac{3}{4}$″ × 2″, with 8 screws for each.

4 pairs of Folding Doors 6′ 0″ × 4′ 0″. 1 Single Door 6′ 0″ × 2′ 9″.

4 ledged flaps for Internal Ventilators 2′ $9\frac{1}{2}$″ square. 8 notched cleets for same.

8 Shelves 11 inches wide 15 feet long; 1 Shelf 6ft. × 1′ 9″; 1 Shelf 5ft. × 1′ 9″.

38 Brackets for shelves : 4 cut brackets, 6 cleets, 3 feet long, for wide shelves.

4 Shelves 6′ × 11″ for store.

4900 $2\frac{1}{2}$-inch cut clasp nails for weather boarding; 2600 2-inch do. for $\frac{1}{2}$-inch inside boarding; 500 4″ do. for ends of rafters and timbers generally; 2800 $2\frac{3}{4}$-floor brads for floors.

2000 Cloak and Hat Pins distributed through the buildings, giving 24 to each hut.

3 10-inch stock Locks.

8 10-inch bolts, 4 thumb latches, 9 pairs 18 inch × Garnet Hinges, 12 pairs Sash Centres and 12 buttons.

Weather Boarding for sides and roof 166 Boards, 5 cut feather edge, 12 feet long, and 112 do. 13 feet long, the 13 feet lengths for the ends, for sides and roof, and the centre filled in with 3 lengths of the 12 feet boards.

Weather Boarding for ends and gables; 47 Boards, 5 cut feather edge, 12ft long.
Do. do. for Porches and store; 33 do. do. 13 do. and 20 do. 14 feet long.

Boarding for inside, sides, ends, and ceiling; 252 boards, 9 inches wide, 5 cut parallel, in 12 feet lengths, and 5 boards do. for store.

Observations and Suggestions on Hutting.

By CAPT. BINNEY Royal Engineers.

In consequence of the serious evils arising from the want of proper cover for the troops during the first part of the late war in the Crimea, a Committee was directed to examine and report upon the different forms of hut in use among the English, French, and Sardinians. The result of their labours is given in the foregoing Report, from which it would appear that the best hut, with the various parts previously prepared, was that known as the Gloucester hut, covered with upright boards having slips or battens nailed over the joints. They however expressed the opinion that it would be better merely to send out scantling of two sizes, and boards, with plenty of nails, for the troops to construct huts for themselves, there being generally a sufficient number of men in every Regiment capable of doing the necessary work.

It is evident that the great desideratum is a hut of such a character that, while moderately warm and able to resist the action of the weather when completed, it will also be capable of being erected in a very short space of time by men of very ordinary capacity, and with materials of the most simple nature and easily transported; but as the above Report has shewn that these objects are not easy to be obtained, it may be well to consider some of the means by which, in the absence of supplies from a distance, the local materials of every kind may be used to the best advantage.

With this view, it would be a great benefit to the service if, at the different camps and garrisons, means were provided for the instruction of the troops in the numerous expedients which may be adopted for obtaining shelter in every variety of position, and a few observations will now be made on some of these expedients, with a view to call attention to the subject and elicit suggestions from those best fitted to give them.

In countries where wood is very abundant, log huts, such as those commonly in use in Canada, may be constructed with little difficulty. The ground is levelled and four poles are set upright at the corners of a rectangle. Two logs are selected, rather longer than the ends of the rectangle, and notches are cut in them to about half their depth near to the ends, so as to fit just outside the posts. These are laid on the ground with the notches uppermost, and two other logs are then selected for the sides, notched in the same manner and fitted over the ends of the others. Another course of logs is laid over these in the same manner, being bound together by means of the notches, and usually still further connected by driving spikes or trenails through them at the junctions. The openings required for the doors and windows must be cut out with a saw, and the door and window frames nailed in the openings against the ends of the logs. The crevices between the logs may be filled in with clay, grass, twigs, or any other soft material, and, where practicable, the whole of the interior may be boarded over or plastered.

If brushwood only is to be had, or larger stuff is very scarce, the plan followed by the Sardinian army in the Crimea is very good in dry soil, viz., that of sinking a hole for the floor of the hut, and forming a roof over it of wattling or hurdle-work, coated thickly with clay mixed with chopped hay or straw, small twigs, &c. (see Report); or the wall may be formed entirely or partly above ground of wattling, and a roof of the same material may be put over it, taking care to secure the angles well, and prevent the weight of the roof, especially when loaded with snow, from pressing out the walls.

If rushes or reeds only can be obtained, the following plans may be adopted. The bundles of reeds or rushes may be nipped (as it is called) between upright posts. The posts are made tolerably even on one side with the axe, and driven into the ground in pairs with the even sides inwards, about two or three inches apart, and the rushes are laid in between the posts, which are then bound together at intervals. Boards may also be treated in the same manner, and the great advantage of doing so is that they are not injured for other purposes. Or, the rushes may be plaited into mats in a variety of ways; posts are then erected at the corners of the proposed hut, and at intervals along the sides, with horizontal bars secured to their tops, from which the mats are suspended. One of the easiest ways of making up the rushes is to lay them in rows and connect them by two small ropes passing alternately round their outsides and insides, and between them, in and out, which are tied at the ends to make all tight. Boards may be made up in the same manner, (as described in that very useful book "Galton's Art of Travel,") but in that case it is necessary to cut a notch at each end for the rope, in order that there may not be an opening between the boards.

In other cases there may not be anything of this kind, and very few sticks or boards to be had. In this instance, the walls may be built either of stone or turf. If of stone, the largest and flattest pieces should be selected and built up as firmly as possible, filling in the interstices with earth so as to make a compact mass, not less than 2½ feet in thickness, if exposed to high winds. If turf is used, the sods should be cut about 2 feet by 1 foot, and six inches thick, and should be built up like brickwork, alternately as headers and stretchers, with the grass turned downwards, small pointed sticks or pickets being driven through to keep the turf together.

In every case it is well to dig a small trench round the hut a little way from the walls; this may be filled at bottom with large stones for the percolation of water, and covered in with turf to prevent accidents.

The roof is the most troublesome part in most cases; where there is plenty of scantling and boards it is of course very easy to arrange rafters in the ordinary manner, to connect them by a ridge piece and collar beams, and lay boards over them covered with birch-bark, or shingles (*i.e.* thin flat pieces of cedar or pine) overlapping like tiles or slates. Branches firmly connected, and placed so as to give a good slope, may also be used to form a roof, with brushwood or straw over them, arranged like thatch. If oiled or tarred canvass or calico can be obtained, a very good temporary roof may be made by throwing the canvass over the rafters without boarding, and securing it at the eaves as strongly as possible to keep it stretched: the same material may be stretched permanently over the boarded roof or sides of a hut in a rainy climate.

Windows may be closed with oiled paper, thin sheets of horn, or, in some districts, with plates of talc; in warm climates *net* is a very good substitute for glass, as it keeps out insects and yet allows of a free circulation of air. Hinges of leather or hide answer very well instead of iron, a second piece or washer being placed to receive the heads of the nails.

The floors may be made of clay, or ashes, and cow-dung, and if both walls and floors be washed several times with a very thin mixture of the same, cracks will be avoided and insects kept away.

There are many other points of great importance to which the soldier's attention might be drawn in the proposed squads of instruction, but these are enough as preliminary suggestions.

C. R. B.

PAPER IX.

Notes on the Mining Operations at Schweidnitz, Silistria, and Brailow, Accompanied by an Account of Recent Experiments in Germany.

By CAPT. J. J. WILSON, Royal Engineers.

Every student of Military Mining must have observed how few accounts of the attack and defence in that branch of warfare are available for his perusal. Experiments have been made in times of peace sufficiently numerous to warrant the construction of rules for estimating charges and their effects; and though for this purpose, on account of the facilities afforded for observing and recording the results, they are more efficient than active operations, still the latter possess a reality and interest which the former can never attain. An attempt therefore to bring together a few facts concerning the employment of mines in former sieges may not be altogether without value.

The following account of the mining operations at the siege of Schweidnitz by the Prussians, in 1762, is taken from the "complete works" of Lefebvre, who conducted the attack. It is sufficiently detailed to enable the reader to follow the steps of the attacking party in their efforts to destroy and pass between the countermines of the besieged, to observe the mistakes committed by both parties, and to draw from them some useful hints as to the best mode of proceeding under similar circumstances. This siege was also the first in which use was made of overcharged mines, and on that account possesses additional interest. Experiments had been made with them before, and the results were satisfactory; but here experiment became experience, and an opportunity was afforded for testing their value in an actual siege.

Before proceeding, however, to Lefebvre's narrative, a short notice of Schweidnitz and the sieges which it sustained previous to the year 1762 may be thought desirable.

Schweidnitz, formerly the chief town of a principality of the same name, is situated on the left bank of the Weistritz, a small stream flowing into the Striegauer, a tributary of the Oder. It was ceded to Frederick II of Prussia in the year 1742, with the province of Silesia. Its fortifications then consisted of a triple wall of masonry, but were strengthened in 1748 by the addition of four detached forts. In 1757, the Austrians, under the command of Count Nadasti, besieged the place with success. No sooner were they in possession than they began to connect the detached forts by continued lines, but had not completed their design before the Prussians besieged and captured the fortress after fourteen days of open trenches. The new possessors added other works, notwithstanding which the place was stormed in 1761 by General Laudun without any preparations for a siege. The works were again improved, and so strengthened by the addition of countermines that when the Prussians became once more the besiegers, under Frederick the Great, in 1762, their efforts were resisted for a period of 63 days. It is but fair however to observe that the garrison was on that occasion much more numerous than in any of the previous sieges, amounting to about 12,000 men.

SIEGE OF SCHWEIDNITZ IN 1762.

The operations of the Prussian attack were directed against the fort opposite to the village of Tunkendorf, their parallel being constructed at about 750 yards from its covered way. From thence two lines of approaches were carried forward, the right hand one being directed against a small flèche somewhat in front and to the right of the fort attacked, while that on the left led up towards the salient angle of the fort itself.

On the night of the 22nd of August the 3rd parallel was commenced, the left hand approaches being then about 98 yards from the covered way. Mining operations were also determined on, and a gallery was commenced from the sap on the left, directed towards the salient angle of the fort attacked. The miners proceeded steadily with this gallery, and on the 28th had advanced 89 feet; but on that night the garrison made a sortie, attacking the sap where the gallery had been commenced and where the guard consisted of but 8 or 10 grenadiers, there not being sufficient space for a stronger party; and as this guard took to flight, the assailants entered the gallery, and made prisoners of a non-commissioned officer and one miner, killing another. Before retiring they pulled down some frames and deposited combustible materials in the gallery.

On the 29th the besiegers' miners repaired the damages, but when all was clear for advancing the work, they were overcome one after the other by the foul air with which the gallery was infected, and which was not got rid of before the evening.

On the 30th, air failing in the gallery, which was now 91 feet long, the Directing Engineer gave orders for the construction of a chamber six feet square. In this chamber was placed a large box containing 125 cubic feet, and within it four smaller boxes well covered with pitch: there precautions were taken to prevent the charge being injured by water, which had made its appearance in the gallery.

On the night of the 31st the charge (5,400 lbs.) was lodged, and tamping was immediately commenced.

This mine was fired at 9 P.M. on the 1st September and produced a crater about 85 feet in diameter and 17 or 18 feet deep. Trenches were now made to communicate with this crater, which was crowned on the 2nd; and on the 3rd a new gallery was commenced from it, directed towards the salient angle of the fort attacked. The tamping was removed from the old gallery and a good underground communication with the crater was thereby provided, which subsequently proved of the greatest service to the besiegers.

The appearance of water in their new gallery, on the 5th of September, prevented the besiegers' miners from continuing it, and they were forced to commence another alongside of it, but at a higher level. With this the besiegers proceeded steadily, and on the 9th had excavated it to a length of 57 feet, but on the same night the garrison exploded a countermine, which damaged the end of the gallery slightly, and wounded the miner at work there. This damage was repaired on the 11th, and the gallery was continued, but soon after the miners had to retire to avoid being overpowered by the foul air caused by the explosion of the countermine. Their retreat was opportune, as another countermine was sprung almost immediately, and with such success as to leave but 6 or 7 feet of the gallery intact.

After having lost 24 hours in endeavouring to repair the injured gallery, another was commenced to its left on the 12th.

On the night of the 13th the besiegers took possession of the crater of a countermine which had been prematurely exploded some days before, and connected it by a sap with their own, its position being somewhat in advance and to the right of the latter.

On the 14th the new gallery had attained a length of 34 feet, when two countermines were fired, one on its right and one on its left, but without doing much damage. The next day, however, the besiegers' miners were overpowered by the foul air caused by these countermines; and, to avoid loss of time, it was resolved to explode a charge as quickly as possible. For this purpose 2,592 lbs. of powder were placed in a box at the end of the gallery, which was 46½ feet long, and tamping was commenced.

On the 16th, at 5 A.M., all being ready, this mine was sprung. and produced a crater 63½ feet in diameter and 16 feet deep, the perimeter of which intersected that of No. 1.* Communication between the two craters was established by the evening, and during the night a traverse was erected for protection against the shells, grenades, &c., incessantly poured in by the garrison.

On the 17th a gallery was commenced from the new crater, but the same night, at 2 o'clock, when it was but 6 feet long, it was destroyed by a countermine, 4 men being buried in its ruins.

On the morning of the 18th the miners were again set to work, but had scarcely commenced a new gallery when it was overthrown by a countermine which took effect in No. 2 crater, killing three miners and wounding a fourth. Another gallery was commenced without delay.

On the 19th the garrison succeeded in overthrowing this gallery also, by the explosion of a countermine, killing at the same time one of the besiegers' miners and wounding another.

A new gallery was at once commenced, but on the 20th, at 6 A.M., when it was 9¾ feet long, it was completely destroyed by a countermine, an officer and two men being disabled at the same time.

On the 21st, a new gallery was commenced to the left of the injured one, which was also carried on, the besieger having managed to effect its repair.

On the 22nd, the explosion of another countermine destroyed the left hand gallery, which had then advanced about 7½ feet.

On the 23rd, a new gallery was commenced by the besiegers close to that last destroyed.

On the 24th the besiegers heard the enemy's miners on both sides of them, very close to the most advanced gallery, which was 21 feet long; and as they feared a repetition of their former discomfitures, a return was at once made, charged with 3,888 lbs., and tamped as quickly as possible. At 10 P.M. the mine was sprung, and produced a crater (No. 3) about 63½ feet in diameter and 17 feet deep, reaching within 10½ feet of the palisades of the covered way. Communications were quickly established between this crater and No. 2.

On the 25th the besiegers commenced two galleries from No. 3 crater; a traverse was also constructed in it to protect the miners, who suffered considerably from the vertical fire of the enemy whilst beginning the galleries.

On the 26th, at 11 P.M., one of these galleries, then 12½ feet long, was overthrown by a countermine. About an hour later the explosion of another countermine partly destroyed the communication between the 2nd and 3rd craters, half burying the grenadiers on guard there. The remainder, with the working party, retired, and a company of grenadiers immediately sallied from the fortress and possessed themselves of the besiegers' craters, destroying the communication between them, as well as the gallery which had not been injured by the countermine, and only retired at daybreak.

* For facility of reference, the craters of the overcharged mines are numbered 1, 2, 3, and 4, in succession, as they were produced.

Lefebvre here remarks that it is surprising that the garrison did not more frequently make sorties upon the besiegers' craters, as, on account of the restricted position of their lodgments, the guard never amounted to more than 24 grenadiers, nor could troops have been brought up in sufficient numbers to their support, without exposing them to the fire of the works in front, as the communication leading to the crater was very narrow. In fact the approaches were not conducted with sufficient circumspection, considering the strength of the garrison. At least, for protection against sorties, lodgments ought to have been extended to the right and left of the 1st crater, so as to be capable of holding a sufficient guard to defend and support the occupants of the craters. This was done on the 27th.

On the 28th, the besiegers, after examination, found it advisable to abandon the communication between the 2nd and 3rd craters. Miners were therefore set to work in No. 2, with orders to make a subterranean passage into No. 3, but having gone deeper than was intended, the gallery thus commenced was ultimately used for another purpose.

On the 3rd of October this gallery was 63½ feet in length. The besiegers also made a covered sap to communicate with No. 3 crater, as well as with the crater of a countermine which the garrison had sprung a little to its left. This crater was crowned, as need was felt of a lodgment for an additional covering party.

On the 4th, towards evening, the garrison fired a countermine a little to the right of the besiegers' gallery, retarding its advance till the following night, in consequence of the miners being overpowered by the foul air generated by the explosion.

On the 7th, about noon, a countermine was exploded on the left of the gallery, but no damage was done, and another, exploded the same night, was equally unsuccessful.

On the 8th, the besiegers determined on preparing a charge, as their gallery had attained a length of 101½ feet; so 5,400 lbs. of powder were lodged at the end of the gallery, and tamping was commenced without delay. During this operation the garrison exploded two countermines, one on each side of the besiegers' gallery, but without success.

About 1 P.M., a powder magazine in the fort attacked, situated under the gorge, adjoining some casemates, caught fire and exploded, by which unfortunate occurrence the whole gorge was blown up from one end to the other, and about 300 men with 2 officers were buried in the ruins.

The besiegers' mine was fired about midnight and produced a very great effect; for although the escarp of the fort was uninjured, such a quantity of earth was thrown up against it as to reach the superior slope of the parapet, and render an ascent practicable.

Immediately after the explosion, two companies of grenadiers leaped into the crater, and glided to the right and left along the covered way, but were met with a very heavy fire of musketry from behind some traverses thrown up by the garrison. This fire, which was kept up during the whole night, inflicted severe losses on the besiegers, causing them to retreat into the craters behind.

During the attack on the covered way, the besiegers attempted to make a lodgment in their new crater, but without success, as it was commanded by the fort, and taken in reverse by the flèche which was the object of the right attack, but which was still in the possession of the garrison.

However, at 9 o'clock on the following morning, the garrison expressed their readiness to capitulate, and the place was surrendered on the 11th of October, after having sustained an attack of 63 days duration, 48 of which were subsequent to the commencement of mining operations.

While the foregoing operations shew plainly the value of countermines in prolonging the defence of a fortress, they at the same time establish the efficiency of the overcharged mine in overcoming the difficulties thus presented to a besieger's progress. In this case everything was favourable to the party attacked. They were well provided with galleries favourably placed for acting offensively against those of the besieger, of whose position they were aware after their sortie on the night of the 28th of August. Their works took in reverse the craters formed by the overcharged mines, which circumstance, as well as the strength of their garrison and the restricted position of the besiegers' lodgments and communications, greatly facilitated sorties. The besiegers too had but one line of subterranean operations during the greater part of their attack; and yet they succeeded in passing through the countermines, and exploding a charge in the position required to effect their purpose, viz., that of making a practicable ascent into the work attacked. The fact seems to be that, over and above the advantage accruing to the besiegers from the power of using overcharged mines of great calibre, and the necessity the besieged are under of using the smallest charges likely to produce the required effect, there is a limit to a long continued efficient use of their own galleries by the latter, arising from the frequent explosion of their countermines. Moreover many of the charges exploded, even though damaging the galleries of the besiegers to some extent, aid in effecting their purpose, by rendering the surrounding countermines less available for defence, either from the vitiated air generated by the explosion, or from the shocks communicated to empty galleries.

It is to be regretted that Lefebvre does not give even an approximation to the lengths of the lines of least resistance of the several overcharged mines exploded by the besiegers, further than recording the depths of the craters produced. However, in a journal of this siege, edited by "Von H——," and published at Hanover in 1774, the lines of least resistance of Nos. 2 and 3 are stated to be 12·36 and 20·6 English feet. They are also mentioned by Bousmard and Mouzé, who, in their essays on military mining, quote the operations of this siege in illustration of the views they bring forward, and the former gives that of No. 1 as 17 feet, but as these authors differ from each other as well as from Lefebvre, I have preferred to adhere closely to the account given by the latter, as he was present at the siege.

SIEGE OF SILISTRIA.*

The Russians made use of overcharged mines at the siege of Brailow in 1828, and again at Silistria in the following year, but principally for the purpose of breaching the walls on either side of the ditch. At the latter place the Turks certainly attempted to thwart their adversaries by countermines; their efforts, however, were so ill directed as in no way to check the operations of the Russians, for they suffered themselves to be forestalled at every point, frequently only by a few minutes, and the charges, when they did explode, scarcely produced any effect, being sprung at the wrong time and place. Nor did they avail themselves of all the means at their disposal, as several shafts were allowed to remain entirely useless. However a short account of the operations may not be found uninteresting.

The front of the fortress of Silistria which was attacked consisted of two bastions connected by a curtain 475 paces long. The ditch varied from 8 to 10 feet in depth, its scarp and counterscarp being revetted with limestone. The scarp was surmounted by a parapet 8 feet high and 20 feet thick, while on the outer side of the ditch was a glacis from 2 to 4 feet high. The exterior slope of the parapet of the bastions was very steep and revetted with hurdles, and that of the curtain with sods. A cunette 9 feet deep, but quite dry, had been excavated, as a precaution against the Russian miners.

* Abridged from "Der russisch—türkische Feldzug in der europäischen Türkei, 1828 and 1829, dargestellt durch Freiherrn von Moltke, major in Königlich Preussischen General stabe." Berlin, 1845.

There were no permanent outworks on this side of the fortress, but some weak intrenchments marked W, R P, on Plate 1, were thrown up by the Turks during the siege, with the view of supplying their place.

The Russians commenced their investment on the 17th of May, and by the 5th of June had completed their 3rd parallel, about 250 paces from the counterscarp. From thence they pushed forwards 6 saps towards the place, and 2 against the intrenchments R and P, as shewn in the plan. Sap No. 1 reached the crest of the glacis first: lodgments were immediately extended to the right and left, and two shafts were commenced. Having attained a sufficient depth, galleries were driven from these shafts towards the counterscarp. Two chambers were then excavated at the end of each gallery, 13 feet* from the wall, and 8 feet below the level of the ditch. The four mines, charged each with 2381 lbs. of powder, were exploded on the evening of the 20th, and not only filled up the ditch, but also destroyed some Turkish countermines, which, as was subsequently ascertained, had been carried forward 62 feet, close to sap No. 1.

In the mean time, the crest of the glacis opposite to bastion A had been reached, and shafts were sunk there also, from which, after they had attained a tolerable depth, the Turkish miners were heard working on the right at no great distance. At midnight on the 20th, a mine (*d*), charged with 1134 lbs. of powder, and having a line of least resistance 21 feet long, was exploded beneath the angle of the counterscarp of the Turkish work W, and completely filled up the ditch. The Turks, expecting an assault, sprung two countermines (*q*, *q*), which were too far in advance to cause much damage. Towards daybreak the two mines (*b*, *b*) in front of bastion A, were completed, the charge of each being 2,438 lbs., and line of least resistance 21 feet. They were fired simultaneously at 9 A.M., and so far fulfilled their purpose that the counterscarp was thrown by the explosion against the face of the bastion, the ditch completely filled up, and the Turkish gallery destroyed. Soon after a mine (*e*) was sprung beneath the angle of the outwork R. During the day the crowning of the glacis and crater were continued, and two shafts were sunk at *f*, *f*, preparatory to firing charges there with the view of throwing down the counterscarp opposite to the right face of bastion A.

The mines at *f* were completed and fired on the morning of the 23rd, producing the same results as those in front of the left face. The crowning of the glacis was continued and two more descents into the ditch commenced. These works were frequently the objects of determined sorties on the part of the garrison; and at mid-day on the 24th, during one of these attacks, the Turks exploded two countermines (*r*, *r*): they did no damage however to the Russian works, as may be conceived from their position. On the same day a battery (*o*), opposite to the postern, was completed, and from the time that it began to play the garrison made no further attempt to enter the ditch. The whole of the cunette was therefore occupied by the Russians, widened, and defiladed by building traverses in it.

On the 25th of June a mine was commenced at *i*, under the right shoulder of bastion B, and soon after a second mine was begun at *h*, beneath the salient angle of the same bastion, for the purpose both of forming a practicable breach and destroying any countermines which the Turks might have constructed there. At 7 P.M. the same day a mine (*g*) was sprung beneath the outwork P, and the garrison took to flight; the Russians therefore took possession of it, and stormed the adjacent works R and W, which had been almost entirely abandoned by their defenders.

During the night of the 25th, the miners in the gallery under bastion B heard the Turks at work somewhere under the right flank of the bastion; accordingly the mine *i*

* It may be here mentioned that in all cases where dimensions are recorded *in feet* in the notes on this siege and that of Brailow, the distances so expressed are in Prussian feet. The difference between the Prussian and English foot (viz. 1·03 to 1) being so small that I thought it undesirable to make the addition of the few inches which would in most instances have been the required increase. The charges however are expressed in English pounds,

was charged as soon as possible with 1814 lbs. of powder, the line of least resistance being 21 feet. It was fired at 3 A.M. on the 26th, and at the explosion, which was very violent, two distinct reports were heard. The Turks afterwards declared that they had sprung their countermine, although not quite ready, the moment they became aware that the Russians were preparing to fire theirs. By the combined action of the two mines the whole flank and part of the curtain were carried away. The other mine (*h*) was exploded at 1 A.M. on the 27th, throwing down the scarp as expected. Its charge contained 1360 lbs. of powder, the line of least resistance being 21 feet long.

The besiegers now carried forward saps from the cunette towards the curtain, and on reaching the revetment broke through it in order to lodge the charges *k* and *l*. Two mines *n* and *n′* were commenced beneath the left flank of bastion A and the adjacent curtain, with the view of making, by their simultaneous explosion, an opening in the main wall, through which the battery on the glacis, marked *t*, would be able to enfilade the adjoining front. The line of least resistance for each mine was 21 feet, the charge for *n′* being 3345 lbs., while that of *n* was only 141 lbs. These mines, finished in 24 hours, were sprung at 8 p.m. on the 28th; *n′* formed an elliptical crater 132 feet by 105, and *n* threw down 38 feet of the flank, thus producing the desired effect.

In order to make a similar opening in bastion B, the Russians carried a gallery beneath its right flank. A gallery was also driven under the curtain at *c*. At day-break on the 29th mine *l* was fired. It had been charged with 1814 lbs. of powder, had a line of least resistance 21 feet in length, and produced a crater 28 feet in diameter, throwing down the revetment. A heavy fire of grape, being directed on the crater, prevented the Turks from occupying it, and an ascent to it was immediately begun. In the evening the mine *k* was sprung with like effect, making the 5th large opening in the main wall. The mine at *c* was now prepared, but at the moment when it was about to be fired envoys appeared from the fortress to negotiate a surrender, and next day Silistria was given up to the Russians, having held out for 44 days after the first investment.

Siege of Brailow.

At the siege of Brailow the mining operations were confined to the formation of breaches in the scarp and counterscarp, no attempt at countermining being made by the Turks. The following description of the Russian mines is taken from the work to which I am indebted for the narrative just given of the operations before Silistria.

It was proposed to place, 1st, an overcharged mine, containing about 11,500 lbs. of powder, at A, Fig. 1, Pl. 2, for the purpose of overthrowing the counterscarp and making an opening in the scarp; 2nd, four mines at B, of 1417 lbs. each, to blow down the counterscarp, and an overcharged mine at C, containing above 11,500 lbs., to make an opening in the flank and curtain; 3rd, four mines at D, and four at E, each containing 1417 lbs., to breach the counterscarp and scarp.

Figs. 2 and 3 show how the besiegers reached the positions of the chambers. A flight of steps led down to a point 14 feet below the Russian lodgments on the crest of the glacis. From the foot of these steps a gallery was carried, at first horizontally, and then sloping downwards to the point *f*, so as to pass under the counterscarp about 8 feet below the foundation. From *f*, a gallery, 3 feet wide and 4 feet high, was driven under the ditch, proceeding steadily across as far as *b*, where the besiegers came unexpectedly upon a cunette 10 feet deep; fortunately they were not perceived, so they retired and refilled their gallery as far back as *c*. Here they sank the floor sufficiently to enable them to pass under the cunette, after which the gallery was driven upwards, so as to reach the point *d*, 15 feet behind the scarp and a little higher than the bottom of the ditch. From this point a gallery stretched, horizontally, to the right and left, parallel to the scarp; and along it, on the side next the wall, were constructed four chambers (E, E, E, E,) at the intervals marked on the plan. A similar gallery, with four chambers (D, D, D, D,) branching from it, was driven to the right and left, from the point *a* parallel to the counterscarp. Thus the central points of the chambers D and E were 24 feet below the surface of the glacis and the crest of the parapet, respectively; and 18 feet and 15 feet from the outer surfaces of the counterscarp and scarp. In determining the charges for these mines, 3 feet (the thickness of the counterscarp), and 6 feet (that of the scarp), were respectively added to the distances 18 feet and 15 feet, thus entering twice into the calculation, and in each case producing the same result, viz.: 21 feet. On this basis the charges of 1,020 lbs. each were calculated, but were subsequently increased to 1,417 lbs. each. The whole of the mines intended to be sprung at the same moment contained nearly 40,000 lbs. of powder. The mines being charged, the galleries *g h* and *o p* were completely tamped, and the gallery *e f b*, from *a* towards *e* and *b*, to distances of 35 feet. The tamping consisted of earth, strengthened with timber, inserted at intervals.

The signal for the explosion was to be given at 9 a.m. on the 15th of June by three rockets: on the ascent of the third the train was to be ignited; and the troops had orders to advance at once to the assault.

At the appointed hour all was ready for the attack; but by a strange combination of mistake and accident the mine at A was exploded too soon, while those at B and C were not exploded at all. The former only threw down the counterscarp. The mines at D and E were fired successfully, and fulfilled their object, forming a practicable descent into the ditch, and a breach 30 to 40 paces wide in the face of the bastion. The assault which followed proved unsuccessful, principally because the failures of the other mines enabled the garrison to concentrate their efforts on the defence of the breach at E.

On the following day the mines at B and C were sprung: the former threw down the counterscarp; the latter merely formed a large crater in the ditch. Other causes however induced the Pacha in command of the garrison to surrender, and the place was given up to the Russians on the 17th of June, 1828.

Experiments made in Germany in 1856.

An account of some experiments lately made in Germany having been placed in my hands, I have much pleasure in attaching it to this Paper, in the hope that they may be found both interesting and instructive, notwithstanding the small size of the charges used. The galleries referred to were nearly all on the same level, none being more than 12 feet beneath the surface; and, with the exception of those particularized, they were lined with gallery frames and sheeting. The dimensions of the main galleries were 3 feet by 5 feet, and those of the branches $2\frac{1}{2}$ by 3 feet. The soil was stiff yellow clay, but the ground had been repeatedly worked over, and was therefore looser than such soil usually is.

No. 1. Charge 560 lbs., line of least resistance $10\frac{1}{2}$ feet, length of tamping 25 feet.

In this, as well as the other overcharged mines, the tamping was strengthened in the following manner: the gallery being lined with close casing, a mining frame was removed, and a wall built across the gallery with large bricks formed of clay worked up for the purpose and dried; pieces of scantling 6 inches square were then laid above one another behind this wall, and firmly wedged in at the ends.

The explosion produced a crater 43 feet in diameter and 13 feet deep. A gallery 28 feet distant from the charge at the same level, and a small branch 5 feet long, at right angles to it, and extending directly towards the charge, were much injured, the former at the point of junction only; both however might still be used without danger. Seven frames were thrown down in a gallery $32\frac{1}{2}$ feet distant from the charge, presenting its side to the effect of the explosion. Another gallery, 27 feet long, nearly parallel to that last mentioned, but on the opposite side of the charge, from which it was distant 19½ feet at one extremity and 32 feet at the other, was destroyed, and the entrance to it blocked up; each of the last two galleries was lined with close casing.

No. 2. Charge 560 lbs., line of least resistance 12 feet, length of tamping 30 feet.

The explosion produced a crater 23½ feet wide, 44 feet long, and 9½ feet deep. Two galleries, one 20 feet, and the other 29 feet distant from the charge, were injured. In the former, which was lined with close casing, 16 cases were thrown down. In the latter one frame was broken. Both these galleries presented their sides to the effects of the explosion.

No. 3. Charge 280 lbs., line of least resistance 11 feet, length of tamping 20 feet.

The crater produced was 39½ feet in diameter and 11 feet deep. In this case there was a gallery commenced from a ditch 49 feet from the charge, and advancing almost directly towards it: a branch extended from it at a point 27 feet from the charge, and making an angle of 60° with it, on the side furthest from the charge. The gallery was much shaken as far as the junction of the branch; and the part extending from the branch towards the mine was completely destroyed: the frames at the entrance from the ditch were also shattered. The branch however received no injury, though passing only about 25 feet from the charge.

No 4. Charge 100 lbs., line of least resistance 11½ feet, length of tamping 15 feet.

This mine, which produced a scarcely perceptible crater, was placed at the end of a branch 11 feet long, leading from a gallery with which it made an angle of 60°. From a point in the prolongation of this branch and 30 feet beyond the charge, a gallery led almost directly up to the chamber, terminating within 3 feet of it. This gallery, formed with close casing, was much shaken throughout, 23 cases being thrown down at the end near the charge.

No. 5. Charge 80 lbs., line of least resistance 12 feet, length of tamping 15 feet.

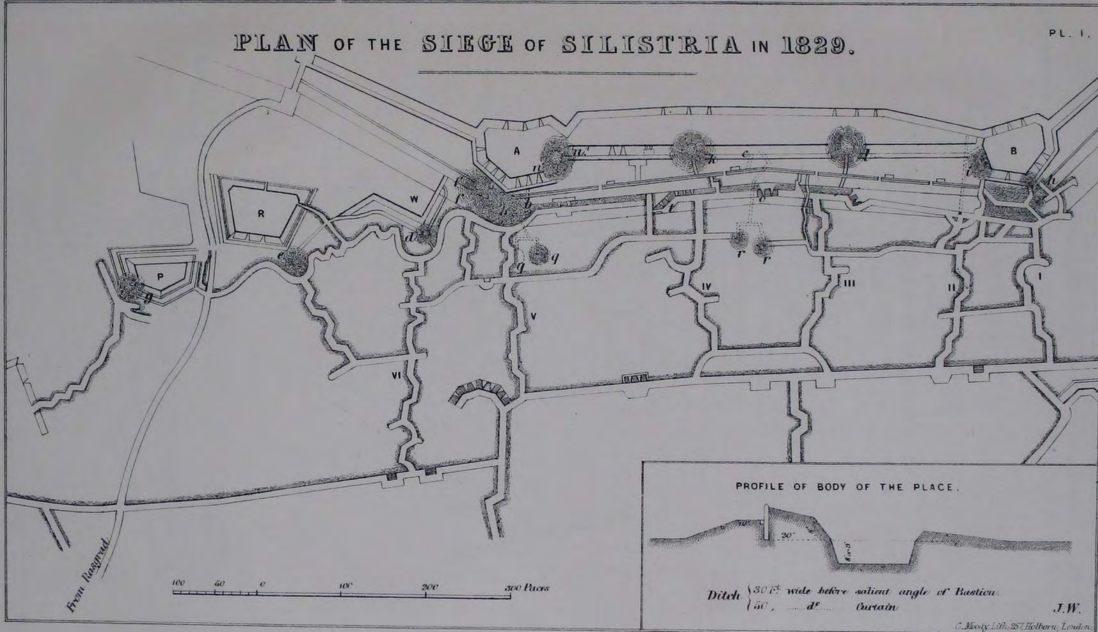
The position of this mine was precisely similar to that last described. There was also a gallery, 33 feet long and formed with close casing, leading towards the charge from the further side, but more obliquely than in the former case, and terminating 4 feet from it. In this gallery 12 cases were thrown down. In other respects the effects of this mine were exactly the same as those of No. 4, for, though the charge was smaller, the soil by which it was surrounded was of a lighter quality. The crater was barely visible on the surface.

In another experiment a charge of 60 lbs. was placed about 3 feet from a mine containing upwards of 200 lbs. of powder, the lines of least resistance being 10 feet and 11½ feet respectively. The galleries leading to them came from opposite directions, and were nearly on the same level; that to the former being straight, while the other had a slight bend near the chamber. The tamping of the larger mine, which extended to about 15 or 16 feet from the charge, was strengthened by two walls built in the manner before described. The small mine, having been tamped to a distance of 14 feet, was sprung, causing considerable disturbance at the surface of the ground and destroying its own gallery for about 14 feet; but, notwithstanding the contiguous position of the other charge, the tamping of the latter remained uninjured, and it was exploded successfully soon after. This result shows the advantage arising from careful tamping, and attests the fact that no movement of any importance can take place in a horizontal direction *unless there be some empty space* within reach of the action of the charge.

It is certainly to be regretted that experiments, such as the above, are generally conducted on so small a scale as greatly to diminish the value of any conclusions that may be drawn from them. It is, however, only by the collection and digestion of all such information as may be within our reach that satisfactory results can be obtained.

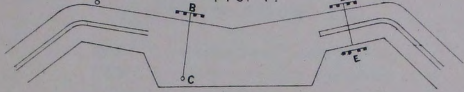
PLAN OF THE SIEGE OF SILISTRIA IN 1829.

PL. I.



SKETCHES
EXPLAINING THE
MINING OPERATIONS
AT THE
SIEGE OF BRAILOW
IN 1828.

FIG. 1.



PLAN OF THE FRONT ATTACKED.

FIG. 2.

PLAN OF MINES.

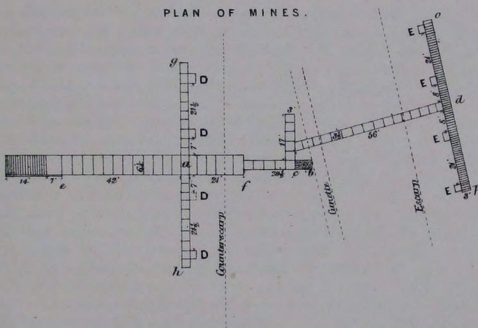
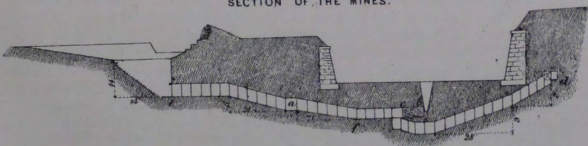


FIG. 3.

SECTION OF THE MINES.



J. W.

C. Moody, Lith. 257 Holborn, London.

PAPER X.

FRAGMENTS ON THE COMPOSITION AND CONSTRUCTION OF MILITARY REPORTS,

BY COLONEL NELSON, R.E.

PART I.—General Remarks and Notices.
PART II.—Illustrations of the Preceding.

"*Il y a des gens qui confondent toujours la routine avec l'expérience.*"—*Histoire de la Guerre par* HENRY LLOYDD.

PART I.

1. These observations are submitted only on the footing of *Contributions;* as the writer conceives that few general rules can be laid down on this subject unless so general as to be liable to pass for truisms: any attempt at detailed absolute instructions could only be empirical and mischievous; they would greatly interfere with that freedom of thought which is indispensable to reporting intelligently: mannerism is as fatal in these simple but important matters as in higher departments.

2. This evil (mannerism) extends to general habits, however valuable in themselves, as well as to details of execution. A recent painter of some celebrity, much given to bold and wild subjects, and remarkable for anatomical knowledge, could with difficulty, it is said, represent a Sylph gathering a flower, without giving her the arms and vigour of a blacksmith at his anvil.

3. In like manner even the highly important habit of aiming at comprehensiveness* may be ill timed and misplaced. As an important general habit and rule—'work from whole to part, and then, reversing the process, from part to whole.' No man handles details so well as when he fully apprehends the "whole" of which they are "parts:" his work will then have a spirit and a meaning in it, even though its relation to the said "whole" be never expressed, and all traces of the constructive methods of forming the Report be carefully removed: nevertheless, it may be precisely the intention of the commanding officer that the general purport shall *not* be known, and that the task assigned shall be simply an affair of detail; then, to that let the reporting officer confine himself.

4. This, however, is not of very frequent occurence with Engineer officers: as a "whole," if possible, every thing should be worked; and if, as in No. 1, (hereafter) three or four almost independent things are ordered for Report, much force will be gained if, happily, some general ground of combination can be discovered, which will relieve the Report from the feebleness of character inseparable from desultory or limited action.

* Comprehensiveness—in reference to *Scope* and *Completeness*—By "Scope" is not intended a morbid and ridiculous tendency to ape the vast and magnificent by the misapprehension and misapplication of gigantic precedents unsuited to present circumstances of time and place. By "completeness" is not meant the finicking triviality that will superintend the driving of every nail; but what is intended and meant is that which, taking the whole subject in all its bearings into full consideration, provides for everything in its full execution of present and future purpose.

5. Every proper effort should be made to obtain *the general intention* of the authority calling for the report; so much does the importance of everything vary with it, and with the day and its occurrences. The best possible Position for yesterday and to-day may be the worst possible for to-morrow. When appealed to for opinion on any extensive operation, how little can be said to advantage without the following formulary being virtually filled in, either from the querist, direct, or from the respondent's resources, mentally!

	What?		What?
	Why?		Why?
With	How?	Against	How?
	Where?		Where?
	When?		When?

6. It should be borne in mind that what is required in a Report is analogous to a panorama, or to the simplest forms of geometrical elevation, not to the pictorial and finished efforts of a painter. The skill of the officer is shewn in simplicity, lucidity, and (as far as may be) brevity,* at least in the Report, however copious may be the Appendices.

7. Hence, " Short Reports and Full Appendices" is a good general rule, but there may be a "mannerism" here too—an affectation of a Suwarrow-like staccato—in which meagre insufficiency is cloaked by quackery and abruptness. It is hard to say which is the worst, this last, or the wearisome but imperfect accumulation of irrelevant matter (at times arranged with extraordinary method,†) with which an unfortunate commanding officer is distressed at a moment when every power of mind and body is already taxed to exhaustion, and can ill afford the vexatious disappointment at a critical moment occasioned by dependence on such broken reeds, such treacherous appliances!

8. The well known formula $S \propto \frac{ad^2}{l}$ holds good in Letter and Report writing, as well as in 'strength and stress of beams,' where S (the strength) varies directly as the *breadth* and as the square of the *depth*, but inversely as the *length* of the subject; especially where the words "breadth," " depth," and " length" have such a peculiar significancy.

9. To 'Report' then, is simply to describe facts *in reference to orders received, and to the purpose in hand*: the same district may be the subject of a dozen successive Reports even on the same point, when the intentions of as many successive commanding officers differ, either from originally varying views, or from circumstances having changed. How different will be the report on a river which is a frontier line, from one on the very same river when it is either abandoned in front, or left for miles in rear!

10. Much time is saved, and much confusion and inefficiency avoided, by a preliminary sketch or analysis of what is generally intended to be done being drawn up by the officer on the receipt of his orders, taking care however not to adhere too rigidly to this scheme, but to be on the *qui vive* at all times for future additions or reductions. This analysis, or constructive skeleton, in its final form, will be the Table of Contents to the Report, which last may be followed by Appendices; the whole being often advisedly concluded by an Index.

* " When a man says *all* he has to say, he will probably say too much "
Anonymous Pamphlet by an Artillery Officer.

† Method has been called the *soul* of business; it is only its skeleton. As far as men are concerned it is but the economy of Power and Time rendered necessary by their limitation.

11. The more completely the ground or other matter in hand can be looked at generally before the detailed examination commences, the more satisfactory will be this skeleton; but such precursory examination is not always possible or necessary, as when a staff officer has to sketch ground for a position with impromptu suggestions from the enemy's tirailleurs. (Vide British Aide Memoire, p. 536, par. A and C, 1st Edition.)

12. In collecting information from almost any source, no single evidence should be, if possible, trusted on any point of the least importance. Putting designedly false intelligence out of the question,—even the very anxiety of well-disposed parties to meet the views of the Engineer, will be a source of error, from their very eagerness not allowing them time fully to answer the questions addressed to them.

13. There is also one person whom the Reporting Officer should hold in especial distrust, if inexperienced and excitable, viz., HIMSELF! The very excitement caused by the interest of the subject will be apt to do the same mischief as in the preceding cases of wilful or unintentional misleading. If conscious of having been so roused, from whatever cause, an effort should be made to see and consider the subject a second time. Much of this liability to error in apprehension, as well as in memory, is saved by noting down the point in writing (or by making a sketch) *on the spot*, as deliberately as may be: this gives the heavy columns of the reasoning powers, outstripped by the light infantry of *imaginative* perception, time to come up to their assistance.

14. With this exception, it is a bad *habit* to rely on going over the same ground twice: as far as possible, 'Finish as you go.'

15. The greater one's stock of general knowledge the more extensive and complete will be the observation. The same subject will be very differently reported on by a well-educated mind, and by a worse informed one, however active and zealous. 'Every point of knowledge, in anywise relevant, is not only an additional light, but a light with a mirror behind it, which reflects the images of all the surrounding lights and objects.' Extensive knowledge has much the character of a multiplying agency.

16. Much is said in certain military works about 'the eagle eye'—about gaining the 'coup d'œil,' &c.; and this is so handled as to leave the student under the impression that it is a natural gift, as unattainable by those who possess it not as the power of using the divining rod.

17. This is mischievous: no man requires the eagle-eye or coup d'œil in drawing on his gloves or his boots; and why? because they are *perfectly familiar operations*, and he does them unconsciously and in perfection. The experienced musician might as well talk of coup d'œil in reading or executing music at sight: true, he does it *now* at a glance; but was this the case when he was learning the notes as a pupil? The like applies to quickness of apprehension in all matters, civil or military, *e.g.* in the relation of ground (or any other subject) to the purpose in hand. They who are as "thoroughly familiar," for instance, with topographical matters as they are with pulling on their gloves and boots, recognise almost at once and unconsciously whether such a district, or route, or feature, or farm yard, or old castle, or mountain range, will or will not answer: they who have not been so educated will be apt to be more or less bewildered; and, bemoaning the want of 'intuitive tact'—'coup d'œil'—'eagle-eye,' &c., &c., stumble through the work as best they may, or retire from it with a painful conviction of the truth of the adage, that 'the groundwork of *all* courage is confidence in your resources.'

18. A man gifted with strong natural abilities, although he has not had a great amount of *systematic* education, often possesses this quick-sightedness to an extraordinary extent in various ways, though he can give no sort of account of it to

others: but what is now contended for is that the so called 'coup d'œil,' 'eagle glance,' 'tact,' &c., in reporting, or in selecting ground, or in tactical movements, &c., is always attainable to a *very respectable extent* when good or even tolerable natural abilities are systematically educated to, and *thoroughly familiarized by long experience* with the subject in question. Ensign Green is inimitable in clubbing a battalion; Colonel Grey is equally so in rectifying the blunder with a light hand and an easy smile.

19. If possible, or advisable, the document should be ended by a concise recapitulation of the heads of report, and of the statement delivered on each respectively.

20. The *Impersonal* should be as much used as possible; the appearance of the pragmatic and the egotistic—sure to defeat its own purpose—is thus avoided. 'It is thought,'—'It is considered,'—'It is suggested,' &c., are far more graceful and *effective* than '*I* think,'—'*I* consider,' &c., which are always offensive, and disparaging to the character of the writer for judgment, except when he is required to do so in order to meet his own proper responsibility.

21. The recommendation to report in distinct, well separated, and numbered paragraphs, with abridged headings in the margin, repeated from the Table of Contents as far as may be, and written in a clear round hand, rather than in one of genteel, indistinct prettiness, may be unnecessary to our junior officers; but it is no small mercy to their seniors, and goes farther than they are perhaps aware of in obtaining a character for ability; especially when accompanied by clear and simple drawings shewing all that is necessary (but no more), and telling their own tale by ample explanatory notices or references, &c., so that each drawing, *as part of a series*, shall, without being overloaded, tell its own tale *almost* independently of the report.

PART II.

The following Papers may be considered as in some respects illustrative of the preceding: they refer to Reports in which the writer was more or less concerned, and it is to be hoped that the many valuable documents by his brother-officers will in like or better fashion be touched on by themselves in future numbers of the Professional Papers.

For a Memoir unequalled of its kind on subjects as referable to the Quarter Master General's Department as to that of the Royal Engineer, see British Aide-Memoire (1st Edition), pp. 534-535, by Lieut.-General Bainbrigge, C.B.; and for a valuable article or Reconnoitring by his son Lieut.-Colonel Bainbrigge, R.E., see Vol. II of the same work.

No. 1.

Report on Part of the Great Fish River, South Africa.

(Vide Professional Papers, Vol. v., pp. 7-15.)

23. The orders from Major-General Sir G. Napier, delivered at Graham's Town through the late Lieut.-Colonel Selwyn, R.E., referred in detail to four almost independent subjects (*a*, *b*, *c*, *d*, below,) with no other general relation than what existed in the Major-General's own purpose of discovering Kaffre marauding routes and the practicability of cutting off the same by Hottentot locations along the Fish River.

24. To meet this "purpose" effectively, it was desirable to find some other subject (A) of their own kind, bearing a common relation to the whole, and thereby to combine the whole intimately but clearly together—a sort of flux to obtain a thorough fusion.

25. To this end, the Report was broken into two parts—1st, the General Report, in which every point, *a*, *b*, *c*, *d*, was successively brought into contact and consideration with the basis A; and then, in like manner, with each other, as shewn in the following formulary, as far as *effective* combinations can be made.

The assumed basis A.—Ground and River considered topographically.

a. Drifts or Fords.
b. Banks.
c. Bush.
d. Hottentot Locations.

A.—A*a*. A*b*. A*c*. A*d*.
ab. *ac*. *ad*.
bc. *bd*.
d.

26. By this means it was conceived that no desirable idea which the Reporter was capable of forming could be omitted. The Report terminated with *bc; bd* and *d* having been disposed of incidentally in previous paragraphs.

27. This algebraical looking formulary was *not* exhibited; it would only have distracted attention, and have been otherwise useless.

28. The *Special* Report (or 2nd part) was thus rendered exceedingly brief, and the Reporter's required and responsible verdict given in a very few words on each head for the information of the Major General Commanding; a most acceptable plan whenever it can be adopted; all reports however, do not admit of this arrangement.*

No. 2.

Report on the Advanced Defences Necessary for Plymouth and Devonport.

29. In 1846, the works at Plymouth and Devonport, as well as some of the neighbouring ground, were inspected by the Duke of Wellington, the Marquis of Anglesea, and Sir John Burgoyne.

30. Orders were given to Colonel Oldfield (then Commanding Royal Engineer), to have the surrounding country examined and reported on afresh.

31. 'Field attack,' from the eastward and westward of Plymouth and Devonport, was the assigned scale of consideration.

32. Hence, in any permanent works that might be recommended, it was only necessary to make the section thick enough to resist field-guns; and by so doing necessarily encumber the enemy with a battering train.

33. The Report was eventually drawn up in four sections; the three first relating to the ground to the westward; and the fourth and last to that eastward and northward, containing also a sort of résumé of the whole in a tabular form.

34. The following analysis, skeleton, or formulary, was followed throughout in examination and report, *as far as each section was concerned therewith;* except that in Section iv, "fords" were substituted for "roads outside the advanced posts." In Sections i. ii. iii. the rivers were all formed in and ran through districts of clay slate and limestone; hence the deep and muddy deposits in the estuaries admitted of little in the way of fords: whereas in Section iv. the rock at, and far below, the sources, was granite and the like; here the sand and gravel brought down produced fords having an important action in the system of defence.†

* In drawing up this Report, the author unfortunately had not his present experience as regards the mischief of egotism to which such pointed reference is made in par. 20.—R. J. N.

† N.B.—Recent changes in the views of the military authorities have called for considerable modification of the *scale* and *detail* of the defences for Plymouth and Devonport. The old report, considered on its own scale, may nevertheless be of service as an example of how such documents may be advisedly managed and arranged, the fundamental ideas, in this respect, generally remaining unchanged in character by mere extension.—R. J. N.

35. Formula for the examination of and Report on the Coast of Devon and Cornwall, from Looe to the mouth of the Yealm.

Attack.

	Facilities.*	Impediments.
Existing	A. Anchorages. B. Pilots C. Landing Places. D. Harbours. E. Resources on landing. F. Roads outside the advanced posts.	G. Prevalent winds. H. Swell, surf, and tide. I. Coast-guard arrangements. J. Roads within advanced posts and water conveyance. K. Defensive positions without works. L. Do. do. with do. M. Billets. N. Engineer resources. O. Commissariat do.
Proposed	Nil.	P. Defensive positions without works. Q. Do. do. with do. R. Alarm posts. S. Patrols, coastwise. T. Do. inland. U. Communications by land. V. Do. by sea. W. Barrack accommodation.
	Impediments.	Facilities.

Defence.

X. Estimate of expense of executing Q.
Y. Do. Superintendence, labour, tools, and stores for preparing P.
Z. Memorandum on the construction of the towers, &c., proposed expressly.

No. 3.

Report on certain Ports on the Southern Coast of the Western District.

36. This was a sort of supplement to the above; drawn up in 1852 in reference to certain secondary places not noticed in the preceding; but the terms were different, and, generally speaking, the circumstances also. It was a conjoint Report by Colonel Morris, R.A., and the writer.

37. They had no longer to do with Plymouth and Devonport, except as centres of support within 24 hours' communication: the position in which they felt themselves at starting is best expressed by the following extract containing their Preliminary Observations.

* All these As, Bs, Cs, &c., should be, in general, suppressed as soon as done with; in the present instance they were retained in consequence of the constant references between the different portions.

In a very secluded village in Germany I once visited the cellar of the very poor and only inn of the place. The equally poor landlord had but two very ordinary wines; but these were ostentatiously noted on the cellar door thus!—

A. Wassenacher.
B. Gleisser. R. J. N.

Introductory Remarks.

"1. The following report is submitted as supplementary to those already forwarded by Colonel Oldfield, R.E., in 1847-48, the whole thus completing the system of defence proposed for the Southern Coast Line of England from the Scilly Islands to Berry Head, the extreme points at which any works exist in the Western District.

2. To preserve, therefore, consistency with those reports, our considerations are given upon the same scale with them, i. e., with reference to field attack only—say at most a division of 8,000 or 10,000 men, or detachments therefrom with only field guns or rockets, but no battering train.

3. The assigned Sections of Report are—

A. Actual condition of the works.

B. Works, repairs, and armament to put them in a state for service.

C. Estimate of time and expense of ditto.

D. Force required for their garrison.

4. As regards B, however, no general military system that we are aware of has as yet been laid down for the defence of England, or of the Southern Coast apart, or even of this its western extremity in particular, to which the subjects of our Report could be referred in their proper relation as more or less significant portions of a clearly determined, well organized whole, embracing conjoint operations of Army and Navy.

5. To avoid, therefore, a random and arbitrary course of procedure as regards the four places visited, viz.: Brixham (including Berry Head), Dartmouth, Penzance, and Scilly, we have been obliged to assume the defence of Plymouth and Devonport as our *basis of consideration*, with the line of the river Dart for the *effective* eastern frontier, as bearing the three towns of Dartmouth, Totness, and Ashburton, along a space of about the last twenty miles of its course.

6. Brixham, as regards this line, may be considered as an advanced point, co-operating with Dartmouth in covering Totness, which is of importance, as the key of nearly all communications from the eastward, either by rail-road, or by the old and excellent turnpike roads still remaining. The " Cavalry Barracks " for perhaps 500 men (still to be seen marked in the Ordnance Survey) attest the importance of this place.

7. To the westward, Penzance is of consequence as the Western Terminus of the English rail-road system, and as a wealthy, enterprizing town in close connection with the most important and active mining district in Cornwall, and also as having a fine pier harbour, and as being situated in a bay of much the same size and form as Torbay.

These two noble roadsteads, Torbay and Mount's Bay, one on each flank of our coast line, with Plymouth and Devonport in the centre, speak very significantly of the part that might be taken by the Navy, often superseding the necessity for much, or even any co-operation with the Army at all.

8. The Scilly Islands, more than any other points, are referable to the protection of a fleet. Of no very great utility in themselves, they would be a source of serious annoyance in the hands of an enemy.

9. No proposal is, however, now made for occupying any of the sites under report on the full or fortress scale: to effect the immediate defence of the harbour, &c., and to hold out for twelve hours, until relieved from Plymouth, is all that is attempted. Nevertheless, it is conceived that what is now recommended may be turned to account as an effective, though minor point, in any more extended plan of occupation that may hereafter be contemplated.

10. We feel also little or no inclination to recommend works for any additional places at present, conceiving that no scheme of fortifications can represent more than the skeleton of defence, and that the active muscle and nerve must be supplied by the manœuvring force, using such works only as points of support; and it is to these forces and to the fleet that we would leave the numerous and tempting points between Torbay and the Scilly Islands, where a vigorous enemy might effect a landing. The fortification of all these would be impracticable, and we submit on all accounts, unadvisable.* In such cases, military roads and defensible barracks for field artillery, cavalry, and line, at well selected points, are probably more to the purpose than regular forts, &c., provided that the serious expenses of either system be well weighed against that of a branch railway from a central military station, estimated at an average of perhaps £15,000 per running mile. We have, however, no authority for entering upon this subject.

11. We now proceed to the more direct matters of report under the preceding heads A, B, C, D, † observing that in forming our estimate of what is required for the establishment or improvement of any defences, we have endeavoured to bear in mind that it should be at least regulated by the importance of the place in reference to—

1st. The general system of defence that is already, or might be, established.

2nd. Its relation to the general national prosperity; partly from its capabilities as a port; partly from the Establishments (naval and military) requiring protection; and partly from the intrinsic merits of the place, estimated by the amount of successful exertion and the importance to which the inhabitants have raised themselves.‡

3rd. The population of the place and surrounding district, with reference to the share they may be called on to take in the defence.

4th. Its utility to an enemy, even if unimportant in almost all other respects, *e.g.* Brixham and the Scilly Islands."

38. It will be observed that the construction of the Reports is much the same as that of No. 1 (par. 25), as far as Brixham, Berry Head, and Dartmouth were concerned: the general "flux" here was the relative position of these places and the River Dart.

* It will be seen that we have even neglected certain dismantled and detached works, as not coming within our present scale of consideration.

† See Appendices 2, 3, 4, for details under these heads.

‡ Compare the enterprising vigour of Penzance, in the mining district, with the feeble though anxious efforts of Brixham, a poor fishing town, unequal even to the establishment of a small breakwater.

PAPER XI.

Remarks on Pontoons, and Suggestions for their Improvement.

By CAPTAIN FOWKE, Royal Engineers.

A pontoon train which would at the same time present the means of constructing an efficient bridge, and be capable of being rendered extremely portable when transport is difficult, has long been a desideratum with military Engineers ; and there is perhaps no one point in which the military equipments of the several great powers present a more marked difference than in the methods adopted for arriving at the solution of this confessedly difficult problem.

In this country we have many competitors for the honor of producing the best pontoon, and individual opinions on the subject seem to differ as widely as the practice of nations; in the Aide-Memoire to the military sciences, under the head of "Pontoon," I find it stated as the writer's conviction, that "a perfect pontoon bridge equipment, combining facility of transport with the quick means of passing armies over considerable rivers, does not seem to have been yet organized;" and, indeed, however perfect we may consider the present beautifully-contrived pontoon bridge, and however well adapted to the state of things existing at the period of its invention, it must be acknowledged that owing to the improvements in the various small arms in use in the service, and the consequent increase in the quantity and weight of the ordnance now brought into the field, considerable modification of the existing bridge equipment seems to be called for, more especially as regards its capability for heavy traffic ; and as it is generally admitted that a greater facility of transport than is afforded by the present system would be desirable, it would appear to be a favourable opportunity for bringing forward a project for a system of pontooning in which great portability and lightness, combined with a considerable increase of buoyancy, are the leading characteristics. Not to add needlessly to the length of this Paper it will suffice if we proceed at once to the description of the proposed system in the following order:—

1st. Construction.

2nd. Method of working.

3rd. Mode of transport : after which will be found a table of weights and dimensions of the pontoon and of its superstructure, followed by a brief résumé of the chief advantages which it is believed may be gained by its adoption.

Description of the Proposed Pontoon.

The pontoon now proposed belongs to the class of *boat*-pontoons, and much resembles in form the wooden "bateau à ponton" in use in the French service, being flat-bottomed, nearly rectangular in plan, and with straight sides inclined outwards, so that it is rather broader above, or on deck, than at the bottom; the bow and stern (see Fig. 1) are alike, and are somewhat similar to the bow of a Thames barge, to which vessel the boat bears a considerable resemblance. It is composed of a wooden skeleton over which is strained stout canvas, rendered waterproof by the application of boiled oil. The skeleton (see Fig. 4) consists of a number of transverse frames or ribs, which are kept in their places by two longitudinal stretchers that run through iron loops in the upper part of each frame (see Figs. 1 and 6), and on withdrawing the stretchers the whole boat is capable of being collapsed like the bellows of an accordion (See Figs. 2 and 3), the transverse frames being permanently fastened to the canvas envelope.

The end portions of the boat are decked with canvas, and the body part is partially covered by a deck of the same material, having however a narrow hatchway along the centre for the convenience of bailing out, or examining the interior of the boat (see Fig. 6); the hatchway also gives the means of using the pontoon separately as a boat, if desired.

The dimensions of the pontoon are – length 23′, breadth 4′ 6″, depth 2′ 3″, length of the body 16 feet, length of each end 3′ 6″. The transverse frames, of which there are seven, are fixed into the canvas at equal distances; over each frame a hoop is laid on the outside of the canvas, and the two are firmly rivetted together with copper boat-fastenings (see Fig. 9). These hoops are ½ inch wider than the frames, so as to project ¼ inch beyond them in each direction; therefore, on the pontoon being collapsed, the external hoops touch one another and form a continuous wooden case or shell for the protection of the canvas; while, from the frames being narrower, a space of half an inch is left between them, which gives ample room for the canvas to fold in without any danger of being chafed or injured by friction. These seven frames form the body of the pontoon, the ends decrease in width to 2 ft. 6 in. at their extremities, where they terminate in transverse pieces of wood or transoms of that length (see Figs. 5 and 6). The transom at the stern has two holes in it at 1 ft. 6 in. apart, and the bow transom has mortices or sockets corresponding to these holes. These are for the reception of the stretchers, which are passed through the holes, and being run through the iron loops in the top of each frame, are directed into the sockets of the bow transom, and, being pressed firmly home, stretch the pontoon to its proper shape, in which position the stretchers are keyed through the stern transom. A small screw jack, shewn in Fig. 10, is provided for each waggon, for the purpose of facilitating the operation of stretching.

As mentioned above, the ends are decked with canvas as far as the first frame, and on these decks are sewn thin ash laths, which are amply sufficient to bear the weight of two or more men for the convenience of anchoring, weighing, &c. (See Fig. 6).

The body of the pontoon is decked along each side up to the stretcher, the canvas being turned up beside the stretcher and forming a sort of combing to the hatchway; and by means of eylet holes along the edges of the canvas, the hatchway could easily be battened down in the event of bad weather or being obliged to form a bridge in rough water.

By means of a diaphragm of canvas stretched on each frame, the pontoon is divided into eight watertight compartments, the two end ones forming air-chambers like those of a life-boat. The stretchers serve also for saddles, the baulks being secured to them, as shewn in Fig. 8, by means of perpendicular pins passing through both, the holes in the baulk being enlarged into slots on the lower side, so as to give it play in a vertical direction ; the baulks are prevented from rising off their pins by the half chesses, which are keyed down at each end to the stretchers (see Fig. 7), with keys of sufficient length to allow of the vertical play of the baulk. The chesses are laid and rack-lashed in the ordinary manner, the oars only being used in this operation. It is proposed to place the pontoons always at a distance apart of 10 feet from centre to centre, as in Figs. 11 and 12, no closer order being requisite even for heavy artillery.

The method of forming a bridge is either by rafts or by booming out from the shore, the latter operation only differing from the same manœuvre as at present performed, to suit the difference in superstructure.

In the Plate, Figs. 13 and 14 shew the method of packing for transport, where three pontoons with their superstructure are carried on each carriage. The carriage is much shorter than the present one, and will probably be somewhat lighter, as the heavy bolsters are no longer necessary ; the wheels are all of equal size, and the same as those of a light 6-pr., thus giving facility for changing or replacing an injured wheel. The draught is rendered lighter, particularly over rough ground, by the front wheels being made larger, and by the axles being brought closer together ; and the carriage is also capable of locking round as easily as a field piece.

	No. in one waggon load.	Dimensions of each Article. length.	breadth.	thickness.	weight of one article in lbs.	Total weight in pounds.
Anchor and Buoy. . .	1				31	31
Baulks.	18	12′ 6″	0′ 5″	0′ 3″	35	630
Boat-hook and oars . .	8	12 6			12	92
Chesses and half Chesses.	18	11 6	2 $2\frac{2}{3}$	0 $1\frac{1}{2}$	$83\frac{1}{3}$	1500
Cable.	1	168			98	98
Lashings.	6					7
Lines.	6					10
Pontoons.	3	23 0	4 6	2 6	260	780
Pins.	36	0 10	0 $0\frac{5}{8}$	0 $0\frac{5}{8}$		18
Rack sticks.	8	1 6	0 $1\frac{3}{4}$	0 $1\frac{3}{4}$	$1\frac{3}{4}$	14
Screw jack.	1				10	10
Stretchers.	6	24 0	0 5	0 3	60	360

	lbs.		cwt.	lbs.
Total. . . .	3,550	or	31	78
Carriage.			13	0
Total. . .			44	78

In considering the proposed pontoon and equipment with reference to their several qualities of weight, buoyancy, &c., the service pattern is adopted as the standard of comparison, the case of a bridge capable of bearing heavy artillery being always taken, as it is believed that, from the increased weight of the guns now brought into the field, that would be the invariable rule in any future operations.

The comparative buoyancy and weight will now be given :—

SERVICE PONTOON.	PROPOSED PONTOON.
The ultimate buoyancy is	The ultimate buoyancy of the proposed pontoon is
cwt. lbs. 61 50	cwt. lbs. 98 3
Deduct the weight of the pontoon and superstructure	
cwt. lbs. 14 68	cwt. lbs. 9 105
Leaves an available buoyancy of	
cwt. lbs. 46 94	cwt. lbs. 88 5
One waggon load of the service pontoon equipment will complete 16 feet of bridge and weighs	One waggon load of the proposed pontoon equipment will complete 30 feet of bridge and weighs
cwt. lbs. 30 102	cwt. lbs. 31 78
So that the weight to be carried for each foot run of bridge is	
316 lbs.	127 lbs.
Or, taking a length of 80 yards of bridge in both cases, there will be required	
15 waggon loads	8 waggon loads*
cwt. 463 total weight.	cwt. 255 total weight.

But as the capacity of a bridge for bearing heavy traffic will depend on its available buoyancy at any one point, and as the canvas pontoon has nearly double the buoyancy of the service one, it follows that in comparing the weights of the two bridges the number of pontoons in the latter must be taken at nearly double ; in which case the weights of two bridges for a river 80 yards wide would stand as follows :—

615 cwt.	255 cwt.

The lengths on the line of march will now be given :—

The length of a loaded waggon is	
19 feet	12 ft. 6 in.
Add to each 27 ft. 6 in. for horses and space of one horse between the waggons.	
46 ft. 6 in.	40 ft.
So that the length of train requisite for 80 yards of bridge will be	
15 waggons × 46 ft. 6 in. equal to a total of 690 feet.	8 waggons × 40 feet equal to a length of 320 feet.

Finally, as regards the *cost* of each :—

It appears that the cost of one of the service pontoons is £50	As nearly as can be estimated the cost of one of the canvas pontoons already made is under £20 say £20,

So that, taking an equal sum for the cost of the waggon and superstructure of each, we have as the approximate value of a waggon and its load—

2 pontoons at £50.	£100	3 pontoons at £20.	£60
1 carriage, say	50	1 carriage.	50
Superstructure, say : . . .	30	Superstructure.	30
Total. . . .	£180	Total. . . .	£140

or taking the same length of bridge, viz., 80 yards,

15 loads at £180 £2,700	8 loads at £140 £1,120

* The number of horses required for these will be 32, and for the others 60.

Abstract of the foregoing calculations, as applied to a length of bridge of 80 yards.

	WEIGHT.	
463 cwt.		255 cwt.
	LENGTH ON LINE OF MARCH.	
690 feet.		320 feet.
	BUOYANCY AT ANY POINT.	
46 cwt. 94 lbs.		88 cwt. 5 lbs.
	COST.	
£2,700.		£1,120.

The following are some of the principal advantages proposed to be gained by the employment of the canvas pontoon.

1. The buoyancy is nearly double.
2. The weight is less than half.
3. The length on the line of march is less than half.
4. The first cost is only two-fifths.
5. The bulk, when packed, is only one-seventh.
6. The height of the roadway above the water is increased.
7. The stability is greater, and the tendency of the bridge to oscillate from side to side is avoided; this motion is caused by the ends of the pontoons being alternately immersed or plunged downwards, and will *cœteris paribus*, always increase as the vertical section of the pontoon approaches the form of the solid of least resistance; and as a flat surface offers considerably more resistance than one with a circular or curved section, it follows that, independently of all considerations of buoyancy, the canvas pontoon will excel in stability from this cause.
8. The liability to damage from shot is diminished, as a grape shot or musket ball, which would make a serious wound in metal, will merely perforate the canvas with a very small round hole.
9. In the case of a pontoon grounding while under a heavy weight, where the metal one would be put quite hors de combat, the worst that would be likely to happen to a canvas one would be the fracture of a frame or two, which would not occasion a leak, and could easily and quickly be repaired.
10. The pontoon can be bailed out easily, even while in bridge; and this operation is no longer dependent on the small pumps, always so slow in action and so likely to choke and get out of order.
11. The weight of every individual piece of the bridge is diminished, as well as the number of pieces, and the superstructure is simplified; in forming a bridge, one operation, that of lashing on the saddles (often a difficult one), is entirely avoided.
12. It would appear from the considerations in the last paragraph that each waggon load could be formed into bridge with at least equal celerity as one load of the service equipment, and, if so, there will be a saving of nearly half the time in forming a bridge, eight waggon loads of the canvas pontoon forming as much bridge as 15 of the service one.
13. The durability is greater: one of the greatest advantages which the canvas pontoon seems to possess over that now in use (as far as can be judged at present) is that while its liability to injury is diminished, in point of durability it appears to be very superior to the latter pontoon, whether on the march, in the water, or in store. Jolting on the march, or rolling over uneven ground, or down a stony beach, is almost certain to start one or more joints of the metal pontoon, slightly perhaps, but sufficiently to admit a small quantity of water, so small as to be disregarded; on being brought out of the water the pontoon is then stored with its inside and all its delicate framework

quite wet, and the process of corrosion, thus commenced, tends still further to weaken the joints and render them even more liable to such accidents; and this accounts for the fact that few, if any, of the present pontoons have ever gone through a summer's practice at Chatham without having to be put at least once into the hands of the tinman for repair. The canvas pontoon, on the contrary, from the elastic and yielding nature of its materials, is less liable to injury on shore; running it on piles or rocks has absolutely no permanent effect on it, for a like reason; and on the march it is enclosed in its own defensive armour of hoops, which effectually protects it from injury. As an example of the durability of such a construction may be cited the case of the fishing boats on the west coast of Galway, which are made of canvas stretched over a wooden skeleton, without any external protection, and which stand all weather out at sea for many years. As to durability in store, I have had an opportunity of very carefully examining 8 canvas pontoons in store at Chatham; of these one was constructed in the beginning of 1853, two more in the course of the same year, and three in the early part of 1855; and although they have all been out repeatedly, and the latter frequently, I think it will be found that they are not deteriorated in any respect: the oldest of all would be perhaps the better of a coat of boiled oil, but nothing more is necessary for any of them.*

14. The canvas pontoon could without much difficulty be made in the field, such materials as hoops of casks, canvas, poles, and oil, being almost always procurable, and one or more extra waggons may be attached to each bridge-train, carrying nine pontoons each, to be available in case of emergency.

15. A *single* pontoon can be used and pulled as a *boat*, for laying out anchors, &c., and as it is stable in the water it may be pulled or poled into its place in the bridge.

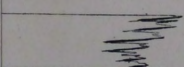
Three pontoons, similar to the one described, have been constructed at Chatham and subjected to some severe tests as to buoyancy; in one instance a heavy 32-pr. was put on a raft of two pontoons and the load was increased by men and sandbags to 95 cwt., with which load it was floated out into the Medway, and it bore it without any apparent strain and with considerable spare buoyancy. The only point in which these pontoons appeared to be inferior to those in use was in the single one of speed in rowing, the expression in the report being that they seemed to be too light to row well; this appears to me to be a matter of such small consideration that I should not have noticed it but for an idea that seems to prevail that the quicker a pontoon rows the better it will ride at anchor in swift currents or rough water, and which every sailor knows to be fallacious, the fact being that the safe riding depends on the *vertical* angle of the bow, while the speed is mainly influenced by the *horizontal* angle or "lines;" a vessel with a bow that is straight up and down will bury her head much more than one with a "flare bow," that is, one which projects beyond the water-line, even though the former may have the superiority in point of speed.

The water rushing against an inclined plane, like the bow of a barge, has a constant tendency to lift the bow, and consequently to counteract the downward pull of the cable, which would otherwise bury the head of the vessel, and by so doing increase her immersed section and throw additional strain on the cable itself. Apart from this consideration the mere question of speed in rowing does not seem to be of sufficient importance to be allowed to weigh for an instant against more important qualifications. Any considerations of speed appear to have had but little influence in fixing

* Three canvas pontoons were sent from Devonport to Chatham by rail and waggon (purposely without instructions as to care and without any covering) and were delivered in perfect order. In 1855 a large canvas pontoon was sent to Paris, travelling by a freight steamer and goods train, and at the close of the Exhibition was in like manner returned in perfect safety (also without any precaution of wrapper, &c.) and it is at least questionable if a metal pontoon would have stood such a severe trial.

HE PURPOSE OF

Scale for Fig. 9 — Full Size.
Scale for Fig. 8 — 1 Inch = 1 Foot.
Scale for other Figs. — ½ Inch = 1 Foot.



Francis Fowke,
Capt. R. E.
1st March, 1858.

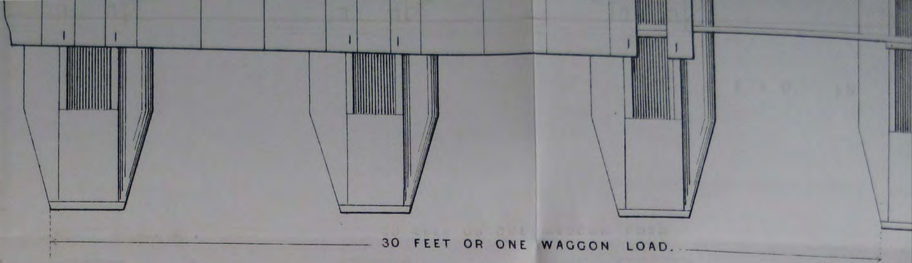


FIG. 12.

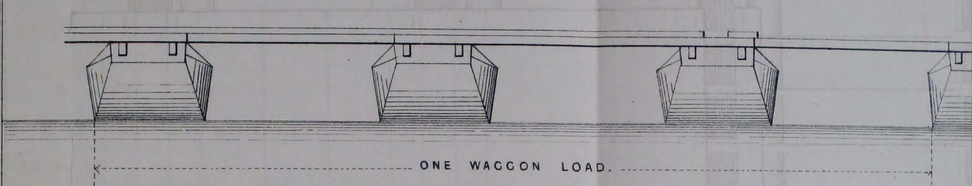
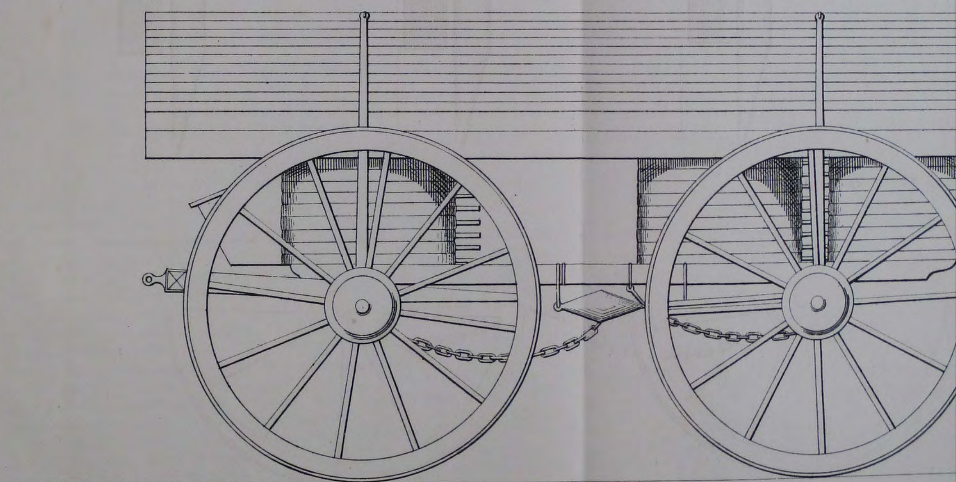


FIG. 13.



ONE WAGGON PACKED WITH THREE PONTOONS AND SUPERSTRUCTURE OF

Scale for Figs. 11 & 12 — 1 Inch = 5 Feet.
Scale for other Figs. — ½ Inch = 1 Foot.

C. Moody, Lith. 257, Holborn, London.

upon the present form of pontoon, the cylindrical pontoon having been inferior in this particular to several of its unsuccessful rivals.

We now come to the inflated *india-rubber* pontoon which was employed with such success at the Cape in 1848, and of which it is said in the Aide Memoire that "it presents so many advantages that it will probably be adopted in our service." The advantages here mentioned are clearly lightness and portability, and I think that it will not be difficult to shew that while the canvas pontoon is superior to the india-rubber one in other respects, it also far surpasses it in those very qualities for which the latter has received so much praise from its numerous admirers. In making these comparisons with the india-rubber pontoon the service pattern will still be retained as a standard.

First, the weight of the three pontoons when ready packed for transport will be stated in pounds—

Service Pontoon.	India Rubber. *	Canvas.
565	413	260

Second, the bulk of the three pontoons when packed for transport—in cubic feet—

Service Pontoon.	India Rubber.	Canvas.
109	17½	15½

Third, the ultimate buoyancy of each of the three pontoons—in pounds—

Service Pontoon.	India Rubber.	Canvas.
6,882	8,127	10,974

By a comparison of the first and third of these tables we get the buoyancy in pounds obtained for each pound of pontoon transported, or

Ratio of buoyancy to weight.

Service Pontoon.	India Rubber.	Canvas.
12	19	42

Again from the second and third we have in like manner the buoyancy in pounds for each cubic foot of pontoon transported, or

Ratio of buoyancy to bulk.

Service Pontoon.	India Rubber.	Canvas.
63	464	708

It would seem from the foregoing tables that in every particular in which the india-rubber pontoon is superior to the present one it is far surpassed by the canvas one now proposed; besides which the latter is free from many of the defects to which the india-rubber is liable. Thus the india-rubber is so delicate as to require to be packed in a case. The slightest puncture is fatal to it, which, in the case of the canvas, would only cause an inconsiderable leak. It has to be kept *air-tight* instead of merely *water-tight*. It is dependent on its inflation by air for its form, consequently on receiving the smallest wound either above or below water, it will collapse.

There will always be a considerable delay in unpacking and inflating. The india-rubber is much affected by temperature, becoming almost unmanageable from extreme cold, and after exposure for any length of time it loses all the properties of india-rubber, and becomes extremely weak and easily torn and broken.

The cost is not stated in the description of this pontoon, but, judging from that of india-rubber goods generally, it cannot, if well made, be much under £100 per pontoon, or nearly five times that of the canvas one.

Of the many varieties of pontoons which have at different times been brought forward it will not be necessary to speak in this Paper, the merits and demerits of all of them having been so frequently discussed in relation to the present service pontoon, which has here been taken as the standard of comparison.

* The india-rubber pontoon weighs 260 lbs., and its packing case 153 lbs. Total 413 lbs.

PAPER XII.

Description of the Temporary Artillery and Cavalry Stabling, and the Royal Engineer Equipment Stabling, Erected at Aldershot in 1856.

By CAPT. COLLINSON, Royal Engineers.

Accompanied by Memoranda on the Details of Construction

By LIEUTENANT L. HALE, Royal Engineers.

Captain Collinson's Report.

Royal Engineer Office, Aldershot,
30th March, 1857.

Sir,

I have the honour now to forward detailed reports of the construction of the temporary stabling for Cavalry and Artillery erected at this camp during the year 1856, which reports have been drawn up by my desire by Lieutenant Hale, R.E., who was in charge of the works in that part of the camp where the Cavalry stables were erected, and by Mr. Lear, Foreman of works, who superintended the construction of the Artillery stables.

The following drawings accompany the reports:—

*No. 1. Block Plan of the Camps, showing the sites of the temporary stables.

Nos. 2 to 5. Plans and Sections of the Cavalry stables.

Nos. 6 and 7. Plans and Sections of the Artillery and Royal Engineer Field Equipment stables.

The following abstract of the circumstances connected with the formation of these stables will explain the reports.

1.—Royal Artillery Stables.

In consequence of the sudden arrival of two Batteries of Royal Artillery at this camp in May, 1856, I applied for authority to erect cover for the horses in as slight and expeditious a manner as would be sufficient to last the summer months. This was granted on May 3rd; and the first Battery of 160 horses occupied their stable on May 13th; the second Battery of 163 horses on May 19th. A considerable part of the time was consumed in obtaining materials; the time occupied in actually putting up the stables, when materials were on the ground, was about four days for the double stable, and ten days for the single stable. The single stable was 15 ft. wide, and the rear wall was partly excavated and partly built up of turf. The double stable was 30 ft. wide. The framework of both was composed of rough Scotch fir poles cut from the

* It has only been considered necessary to print a portion of these plans.—Ed

government property, the roofs being covered with canvass, and the walls thatched with fir-tops; and they were erected entirely by working parties of soldiers, of whom the chief part were of the Royal Artillery. Four feet lineal per horse was allowed in both stables. They cost £434. The single stable is now standing (though re-contructed) being Nos. 4 and 5 on Plan No. 1.

In consequence of the arrival of more Artillery in camp, and of a notification from the Lieutenant General Commanding that it was desirable that the whole force of Artillery should be accommodated in temporary stabling during the winter, I applied on July 30th for authority to expend £1,500 upon re-constructing and adding to the original stables to make them fit for the accommodation of four Batteries and one Troop, the strength of which then amounted altogether (including officers) to 740 horses. I received the authority on August 14th; on November 18th the Barrack Master took over the re-constructed stables, excepting the original double stable which has been re-constructed since. Plan No. 1 shows the arrangement of the new and re-constructed stables now standing. All the new stables were double and 30 feet wide; the framework being composed, as before, of rough poles of Scotch fir, and the roofs being thatched with straw, and the walls with heather. Plan No. 6 shows the section of them.

Mr. Lear's Report (marked A) shows in detail the material, time, and labour, expended upon a length of 212 feet of double stable as it now stands, which length has been selected for facility of comparison with another stable built for the Royal Engineer Field Equipment Troop. The material is that quantity in the stable at the date of the Report. The labour and time has been taken from the books of the office. By this it appears that this length of stabling cost about £300, and the total weight of material is 78½ tons for 212 feet of double stabling, covering 100 horses. That is about £3 and 0·78 tons per horse.

These stables were also built almost entirely by the Troops. Those of the Royal Artillery assisted very materially by their superior intelligence and steadiness. Some civilians were employed in sawing and thatching and carpenters' work, owing to the want of artificers among the Troops.

This mode of construction makes a very comfortable, neat, and durable stable, and one that can be erected by the Troops under proper superintendence in any country where timber and straw is procurable. It is however expensive, and the weight of material per horse is very great, being half as much again as that of a completely boarded stable, and four times as much as that of a canvass-roofed stable. This weight would become a very serious consideration if the material had to be transported any great distance, and therefore I do not recommend its adoption except in a country where the material is at hand and where the horses are likely to remain for a few years on the same spot. The single stable (with one side excavated) is a more comfortable one than the double one, but it consumes much more labour and material per horse, and I do not recommend it unless the ground is favourable for the excavation.

2.—Royal Engineer Field Equipment Stables.

The stables for one troop, of 85 horses, of the Royal Engineer Field Equipment were ordered to be erected on the 27th September, 1856. They were completed by the end of November, at a cost of £678.

The detail of the labour and materials consumed in the construction of these stables is given in Mr. Lear's Report (marked B), and Plans Nos. 6 and 7 show the construction.

The site was selected in order to be near to the huts occupied by the remainder of the Royal Engineer Force, and to the pontoon wharf; and in order to afford a comparison between stables constructed of different materials, these have have been made of rough Scotch fir poles covered with boards throughout.

It appears, by Mr. Lear's Report, that the cost of the stable alone, 212 feet long, (including all materials as it stands, and a proper proportion of the labour on the whole as taken from the books) has been £300, to cover (including space for forage) 85 horses, or £3 5s. per horse, and that the weight of material in the stable is altogether about 41 tons, or 0·5 ton per horse.

This stable is more comfortable and durable than any temporary stable erected here ; but unless the situation be easily accessible, for the supply of timber, it would be considerably more expensive than any other : in fact a thatched stable would never be adopted unless straw, or some other suitable material, was near at hand, which would keep down the expense of that material.

3.—Cavalry Stables.

On the 8th May, 1856, the Inspector General of Fortifications authorized me to commence providing temporary stabling for the summer months for 1,000 Cavalry horses. On the 15th July, these stables, together with two forage barns, were completed, at a cost of £300. The framework of them was composed of rough Scotch fir poles, and the roof of canvass, which was obtained from the government stores (being the same as that used at the Chobham Encampment in 1852), and the sides were thatched with fir tops. Almost the whole of the work was executed by soldiers.

On the 30th July, in consequence of a representation from the Lieutenant General Commanding at the camp that it was considered desirable that the Cavalry should remain here during the winter, I applied for authority to spend £400 in reconstructing these stables to fit them for the winter. On the 14th August this authority was received, and on the 17th November they were delivered over to the Barrack Master, namely, 13 stables, each 210 feet long, for 1,000 troop horses, 60 officers' horses, and 60 sick horses, together with two reconstructed forage barns. These stables were constructed of rough Scotch fir poles, obtained partly by contract and partly from government property. The roofs were constructed on the principle on which Arctic voyagers house their ships for the winter. A strong ridge pole is supported by upright posts along the centre of the stable, with 3-in. rope rafters extending to the walls on each side, and thence to pickets in the ground ; and the canvass is laid over these in one piece, 210 ft. × 32 ft., and 2-inch rope rafters over the canvass, at each under-rafter, and secured to the same pickets.

Some canvass roofs were single, and coated with waterproof composition, and some had a double thickness of canvass. The chief part of the canvass was drawn from government stores, and the rope was obtained from the Admiralty dockyards. The ventilation was finally provided for, partly by openings in the roof, with canvass outside, and partly by openings in the boarded walls. The walls were all boarded on the slope of the exterior struts.

Lieutenant Hale's Reports, (marked C and D) describe so exactly the construction of these stables that it is unnecessary for me to go further into detail. The site was selected in conjunction with the Assistant Quarter Master General of the camp, but was intended for summer stables only, and is too far from the huts for winter stables. The well is not found sufficient to supply the whole force ; part of them have had to water at the canal, about one mile from the stables. The labour was executed chiefly by soldiers from different regiments in camp, as will be seen on reference to the table drawn up by Lieutenant Hale (marked E). The Cavalry supplied very little labour in comparison with that supplied by the Artillery in their stables. The soldiers were all paid the regular amount of working pay. The artificers remained at the work during nearly the whole time, but the military labourers were frequently changed. The greatest part of the time occupied in the construction of these stables was consumed in obtaining the materials. The time occupied in erecting the summer stables, after the materials were on the ground, was, (by Lieutenant Hale's calculation) about four days per stable 210 feet long.

The four stables mentioned in Lieutenant Hale's Report, marked D, which were reconstructed altogether on a different site, out of the old materials, are those which I recommend for your special consideration, as exhibiting the best mode of construction of all that we have used at this camp, for a temporary stable for general use in Her Majesty's service.* The total cost of it, calculating the whole of the materials as they stood in the stable at the time of completion, and taking the labour from the office books, was about £197 per stable 219 feet long, or about £2 per horse, reckoning 4 feet lineal for each. The total weight of the materials of one stable, according to Lieutenant Hale's calculation, was 19 tons, or 0·19 tons per horse. It is in consideration of the small weight of the materials, as compared with a thatched or boarded stable, that I recommend the canvass roofed stable. The materials are such as can be more easily obtained than those for almost any other construction. The rough poles are supposed to be procurable on the spot; the canvass and rope could be supplied from any sea-port town, and from any of Her Majesty's ships; the walls could be constructed of turf or stones, as the nature of the country allowed, and the stables could be taken down and rebuilt with less waste of material than in any other construction.

With respect to the increased cost and time of construction, and quantity of materials in the stables constructed this year at Aldershot, over some of those constructed in the Crimea during the late war, especially those built by the Sardinian troops, I beg to point out that in our service it is considered necessary that even temporary stables should be weathertight, well ventilated, and partially paved, and that the horses should be, to a considerable extent, separated from each other.

I have the honour to be, Sir,

Your obedient servant,

T. B. COLLINSON,

CAPT. COM. ROYAL ENGINEER.

To the Inspector General of Fortifications.

* See Fig. 5.

Memoranda on providing Temporary Accommodation for Twelve Hundred Cavalry Horses, in the North Camp at Aldershot, agreeably to the Order of the Inspector General of Fortifications, dated May, 1854.

By LIEUTENANT L. HALE, Royal Engineers.

The site selected as a summer encampment for cavalry, by the officers of the Quartermaster General's Department, is a flat piece of heath situated between the northern boundary of the Government property at Aldershot and the north end of the north camp. The fall, which is very gradual, is in an easterly direction, and space was reserved on the east side for tents.

The soil consists of sand, lying under a thick black 'rust,' and is such as to be very dusty in dry weather, and very muddy when wet: but there being no other ground near the camp available for this purpose, the inconvenience was unavoidable.

Water was obtained in ample quantities from a well sunk at the point marked A on the accompanying plan of the ground.

The order to commence the stables having been given by the Commanding Royal Engineer on the 22nd May, the work was commenced on the 24th, the interval having been employed in collecting materials, &c.

It being necessary to complete the stables as rapidly as possible, materials were chosen of which there was a large supply at hand at the time, viz., rough fir poles, canvass and rope.

On and near to the Government property in the neighbourhood are large plantations of Scotch fir and larch, and great quantities of brushwood and heather.

The plantation at Pyestock, on the Basingstoke canal, and that on the Farnborough and Farnham Road, were most favourably situated as regards the transit of materials; and the cost of cutting, and delivery of the trees on the ground, was very trifling, averaging about fourpence each.

The accompanying table of military labor and pay does not include that spent in felling and conveyance.

Large working parties from the troops in camp were employed in digging holes to receive the upright posts, while military artificers were engaged in preparing the wall-plates, rafters, &c. At the same time civilian thatchers, and men of the same trade procured from the troops, were employed in making hurdles for the sides of the stables. These hurdles were of brushwood, furze, and heather.

On the requisition of the Commanding Royal Engineer, a party of naval riggers, under charge of a boatswain, was detached from Portsmouth Dockyard, by order of the Admiralty, to assist in making the canvass roofs.

When the construction of the stables was altered, by the substitution of rope rafters for those of wood, these men were almost indispensable for the proper execution of this portion of the work.

The relative positions of the various buildings is shewn in the accompanying plan marked No. 1.

The first five stables were constructed on the plan shewn in the drawing marked No. 2 *

Each stable was capable of containing one hundred horses,† and was 200 feet long and 32 feet wide at the ground line. A passage, 6 feet in width, ran down the stable between the central uprights, and 8 feet was allowed for each horse's length.

The horses' heads were turned to the centre of the stable, and the distance from their heels to the line where the hurdles rested on the ground was 5 feet.

In each stable were four rows of upright posts.

The outer rows of trees were composed of trees of from 4″ to 6″ in diameter. They were 8′ 6″ in length, and were sunk 2′ 6″ in the ground. The inner rows were composed of trees of from 6″ to 8″ in diameter; they were 14′ in length, and were sunk 2′ 6″ in the ground. These latter were connected at top, and a wall plate was maintained in a proper position by collars about 3″ in diameter and 7′ in length. The wall-plates were about 3″ in diameter.

From the top of the outer uprights passed rafters, (of rough trees, about 4″ in diameter at the centre), resting on the upper ends of the inner uprights, and crossing at top so as to support a ridge pole about 4″ in diameter.

The thrust of the rafters was counteracted inwardly by the horizontal collars, and outwardly by struts (about 4″ in diameter) supporting the outer uprights. These struts likewise carried a tree (almost in the position of a wall-plate) not more than 3″ in diameter, to which the canvass roof was lashed down.

‡ The canvass used for roofing the stables was that known in trade as No. 4. The dimensions of a canvass roof when placed on the ground were—

Length, 201′; Breadth, 30′.

The canvass was made up into roofs, partly from 2′ breadths, and partly from roof-pieces, each 14′×30′.

In some of the stables the breadth of canvass over the ridge-pole was puckered at the seam with a view to ventilation. The liability of the pucker to fall inwards, and to form an entrance channel for the rain, quite counterbalanced, however, any advantage to be gained from the increase of ventilation. The roof was laid on the ground along the whole length of the building previous to raising it over the frame-work. Lines were then attached to one side of it; these were thrown over the ridge and the roof was then hauled across.

The effect of the working of the canvass on the rough rafters soon made it apparent that unless some other material was made use of as a support, the canvass would repeatedly require repair, more especially at that period when it would be the least advisable to expose the horses to the weather, namely, during the winter. The Commanding Royal Engineer determined therefore to carry out the plan adopted by the Arctic voyagers for their canvass coverings, and to substitute rafters of *rope* for those of wood. At first only one-half of the rope rafters were substituted for those of wood, but eventually the whole of the wooden rafters were dispensed with.

Some alteration in the construction of the stables was consequently rendered necessary, and this was effected as follows:—instead of the two inner rows of uprights, one central row was adopted. These supported a stout ridge-pole, which was further strengthened by struts connecting them with the central uprights. At a distance of 5′ from the feet of the outer rows of uprights, strong pickets about 3′ 6″ in length were driven 2′ 9″ into the ground.§

* See Figs. 1 and 2.

† The number was afterwards reduced to 84, to allow space for harness.—T. B. C.

‡ This was obtained from the Tower and had been used at the Camp at Chobham.—T. B. C.

§ See Figs. 3 and 4.

The rafters of 3″ rope, with an eye at each end, took one turn over and round the ridge-pole. Each end passed round the wall-plate to which the roof was lashed, and round the outer upright and strut, in such a manner as to press them firmly together, and to strengthen the other lashings, &c., by which they were connected with each other, and was finally connected with one eye of a double-eyed piece of rope (the other eye of which was attached to the picket) by means of lanyards of 2″ rope: the rafters could thus be made taut or otherwise, at pleasure. The canvass was lashed to the wall-plate as before, and the ends of the stables were in all cases protected by triangular pieces of canvass.

As fast as hurdles could be made they were brought up from the canal, by the side of which the materials for making them were deposited: they were laid against the struts, and occasionally canvass sides were used temporarily. Each hurdle was 8′ × 8′, and they could be made at the rate of $1\frac{3}{4}$ per man per diem. The weight of each hurdle was 1 cwt.

The above details, together with the tracings accompanying this report, are, it is presumed, sufficient to illustrate the construction of the stables.

During the early progress of the stables the cavalry were obliged to go a long distance for water, but an abundant supply was at length obtained from the well to which allusion has been made in the earlier part of this report. The well, for a depth of 18′ from the bottom, was 8′ wide in the clear: it was then contracted by a dome into a shaft 4′ in diameter, and its whole depth was 26′. The steining was in equal proportion of dry and cement work up to the springing of the dome, but from thence to the top in cement. At the bottom of the well chalk was deposited 2 feet deep.

Great difficulty was experienced during the progress of sinking; at about 8′ from the surface the sinkers came to a running sand, which retarded the work to such an extent that in one period of twenty-four hours the well was sunk not more than 3″. Gangs of civilians were employed for a great portion of the time, day and night, but the well was only completed after 63 days of hard labor. The total cost was £232 10s. 6d., or £8 18s. $10\frac{1}{4}$d per foot.

The supply of water obtained was, however, such as to compensate for the labor and expense incurred, for when upwards of 1,000 horses were making daily use of the water there was at least 13′ of water standing in the well after the night's disuse.

The period occupied in erecting stabling for the 1,200 horses was, at the outside, from May 24th to July 19th, a period of 55 days; excluding Sundays, this is reduced to 48 days; and deducting, still further, 3 days for bad weather, and for the time when the troops were withdrawn from the works for the grand reviews, which were then on a very extensive scale, the total time occupied was 45 days.

In addition to the 12 stables, 2 forage stores, (each 96′ × 26′) and capable of holding nearly 20,000 rations, were erected within this period, so that, taking the labor on the stores as equal to that expended on one stable, $3\frac{1}{2}$ days were occupied in providing both forage stores and shelter for 100 horses.

In the following remarks the days of employment of officers are omitted from the calculation, the smallness of the number justifying this; and it is assumed that 4,466 days of a workman were occupied in constructing the stables and in superintendence. It was found, in fact, that from the work being carried on near the camp, the presence of an officer of the Line was unnecessary.

The men, (the artificers especially) took a great interest in the work, and on hardly any occasion, if ever, did insubordination or noisy behaviour become apparent among them.

Assuming therefore the number of men to be 45, and taking the forage store as equal to one stable, it appears that the time of about 98 men was occupied for $3\frac{1}{2}$ days in erecting stabling and forage sheds for 100 horses. This cannot be considered slow work when it is remembered that many of the laborers had never before touched shovel or pick, and that many of the artificers were very inferior workmen, though necessity obliged us to make use of them in that capacity. The Sappers are of course included in these tables under the same heads as the other troops, but most of their time, that of the laborers especially, was employed in superintending the work.

Dividing the number of non-commissioned officers by 13, and again by 3½, the result shews the daily proportion of superintendence to have been about 5 per diem, or 5 per cent, which is the proportion authorized by the Queen's Regulations. Similarly we obtain the daily proportion of artificers as 33, and that of laborers 59.

The cost of non-commissioned officers' superintendence at each stable, for the 3½ days,

	£	s.	d.
was, at 1s. per day.	£0	17	6
The cost of artificers, at 2d. per hour.	7	8	2
Do. laborers, at 1d. do.	7	0	0½
Officers' superintendence.	0	8	6
Military labor.—Total.	15	14	2½

	£	s.	d.
That of civilian thatchers, at 2s. 8d.	£1	9	6½
Do. sawyers, at 4s. 9d.	0	16	9¾
Boatswain and riggers, at 1s. 4½d.	1	1	4
Naval and civilian labor.—Total.	3	7	8

The total cost of labor alone on the ground was about £19 1 10½ per stable
or 248 13 8¾ for the whole.

The number of trees used in the whole 13 stables was about 2358, or 182 per stable: of these about 50 were used as rafters, 56 as wall-plates and ridge-poles, and 75 as uprights, collars, &c. We may estimate the cost of these, delivered on the ground, at 4d. per tree, or £3 0s. 8d. per stable.

The canvass roof was of old canvass, but the price must be taken as that of new canvass, viz.: 2s. 1½d. per yard superficial; the total cost therefore of canvass would be about £914 11s., or £70 7s. per stable. The entire quantity used was 8,710 yds., and the weight of each roof, 6 cwt. 0 qr. 14 lbs. The quantity of rope used was 2,000 fathoms of 3″, or 154 per stable, and 1,000 fathoms of 2″, or 77 per stable.

The weight of rope on one stable was—	cwt.	qrs.	lbs.
3″ Rope.	3	1	5
2″ Rope.	0	3	8
	4	0	13

The cost of rope was—

	£	s.	d.
3″ at per lb. 9d.	£13	16	9
2″ at per lb. 9d.	3	9	0
Total cost.	17	5	9

The weight of trees we may estimate at 50 cubic feet per ton. The content of the trees of each stable was 404½ cubic feet, and the weight about 8 tons.

About 154 brass eyelet-holes were used in each stable, and the weight, per stable, of these, including the lashing ropes, &c., we may estimate at 2 cwt. 2 qrs., and the cost at £2 10s.

50 hurdles were required for each stable.

The total cost of each stable was therefore—

	£	s.	d.
Military labor.	£15	14	2¼
Civil do.	3	7	8
Canvass.	70	7	0
Rope.	17	5	9
Trees.	3	0	8
Well sinking	17	17	9
Eyelets, &c.	2	10	0
Total.	130	3	0½
viz., for one hundred horses,—or per horse.	1	6	0¼

The total weight of each stable was—	tons.	cwt.	qrs.	lbs.
Canvass.	0	6	0	14
Rope.	0	4	0	13
Trees.	8	0	0	0
Hurdles.	2	10	0	0
Et cætera.	0	2	2	0
Total.	11	2	2	27
viz., for 100 horses,—or per horse.	0	2	0	25

The plan on which the first stable was constructed was certainly faulty. The canvass was very quickly torn by working on the rafters, and from the moment that a rent was made in it the speedy destruction of the roof became a certainty. The trees were very slight, and the force of the wind had by the end of the summer twisted the framework in all directions. From the experience obtained on this occasion, it seems necessary in future to increase the width of the passage between the horses' heads. Not only did the animals fly at one another, but in both the double and single post stables they in many instances gnawed nearly completely through the posts. This was, however, in the last erected stables, prevented by tarring the posts. Owing to the desire manifested by the authorities to get the horses under cover as soon as possible, the very slightest levelling of the sites had to suffice, but it would have been infinitely preferable to have levelled and drained (French) the stables previous to occupation.

It was evident that with old or badly sewn canvass these stables afford sufficient cover only in a climate free from heavy showers and severe winds; but with good canvass and boarded sides, and a few minor improvements, the single post stables would form excellent cover where permanent accommodation cannot be procured.

LONSDALE H. HALE, Lieut. Royal Engineers.

December 1*st*, 1856.

Memoranda on the Construction of Four Cavalry Stables at the North Camp, Aldershot, in the Autumn of 1856.

By LIEUTENANT L. HALE, Royal Engineers.

During the autumn of 1856, four entirely new stables were built for the accommodation of a portion of the Cavalry proposed to be stationed at Aldershot Camp during the winter. Those which had been occupied during the summer were of too slight a construction to stand the storms of winter, they were therefore nearly all pulled down and rebuilt.

The site chosen for four out of the number was a piece of ground to the west of the summer stables. These four form the subject of the present report.*

The general construction was almost identical with that of the single post stables, having the rope rafters described in the last report. The central uprights were 17′ 6″ in length, sunk 2′ 6″ in the ground, and about 8″ in diameter. The number varied, fourteen being the best. The central posts were nearer to each other than the rest were, the distance between the others averaging about 16 ft. The ridge-pole was about 3″ in diameter. The outer uprights were 9′ 6″ in length, 2′ 6″ in the ground, and 6″ in diameter. The wall-plate was formed of half trees, 4″ in diameter, fitted into notches in the outer uprights. The struts were 4″ in diameter, about 9′ 0″ in length, and 1′ 6″ in the ground. On one side, at the top of each outer upright, was a small stud carrying a board, which was intended to prevent the water from the roof falling inside the stable. This was necessary where the canvass did not come down much lower than the plate; but in these stables the canvass came down nearly 1′ 6″ on each side.

The sides of the stables were protected by old weather-boarding, a large quantity of which had been left in the camp by one of the contractors. The value of it had been very much deteriorated by exposure to the weather, and the price at which it was purchased by the Royal Engineer Department was 1⅛d. per foot lineal. The lap was about 1½″.

Two of the stables had double coverings of canvass. In all the four, ropes were passed over the canvass and were made fast to the eyes of the ordinary rafters. By these means the canvass was steadied during the severe weather. The rafters at the ends of the stables were of wood.

The ventilation was effected in three ways. 1. At intervals along each side of the stable a piece of weather-boarding about 5 feet long was made to lift up and down on leather hinges: there were about 6 in each stable. 2. A canvass door, about 4 ft. square, in a wooden frame, was fixed in each gable end. 3. On each slope of the roof three trap-doors of canvass, about 2 feet square, were fitted, and supported by a frame-work of wood extending from wall-plate to ridge-pole. The sides of the openings were protected by canvass flaps, and a pole about 3 feet long was fixed upright into the ridge-pole. At the top, on one side, was a pulley, a piece of line passing from the lower part of the shutter over the pulley, and thence into the stable through the canvass, affording means of increasing or diminishing the ventilation.

At either end of the stable was a door, and there were about three on each side. To insure the speedy removal of the horses in case of fire, the weather boarding was sawn through at intervals, so that portions of the sides could be easily knocked out. The horses' heads were turned from the centre of the stable. The slope was from the centre, and the stables were kept dry by numerous drains. The double canvassed stables were very dark, but if the canvass is good the single is preferable.

* See Fig. 5.

The actual cost of the stables was as follows :—

LABOUR.

			£	s.	d.	
Civilian sawyers. . . .	32 days,	at 5s. 6d. . .	8	16	0	
„ carpenters. . . .	220 „	at 4s. 6d. . .	49	10	0	
„ boatswain. . . .	14 „	at 1s. 10½d. . .	1	6	3	
„ riggers. . . .	84 „	at 1s. 4½d. . .	5	15	6	
Royal Engineer carpenters,	268 „	at 1s. 0d. . .	13	8	0	
„ „ tailors. .	44 „	at 1s. 0d. . .	2	4	0	
Line carpenters. . . .	248 „	at 1s. 4d. . .	16	10	1	
„ labourers.	348 „	at 0s. 8d. . .	11	12	0	
„ tailors.	152 „	at 1s. 4d. . .	10	2	8	
			119	5	1	or £29 16 3¼ per stable.

MATERIALS.

			£	s.	d.	
Fir trees, large size. . .	320	at 4s. 8d. . .	74	13	4	
„ „ small „ . .	500	at 1s. 7d. . .	39	11	8	
3″ rope, 800 fathoms. .	9 cwt.	at 65s. 0d. . .	29	5	0	
2″ „ 1400 „ . .	9¾ „	at 65s. 0d. . .	31	13	9	
Hut line 2500 feet. . .	2½ „	at 45s. 0d. . .	5	12	6	
One covering of canvass,	2992 sq. yds.	at 1s. 10½d. . .	280	10	0	
Coal tar.	36 gal.	at 0s. 6d. . .	0	18	0	
Gravel.	500 „	at 2s. 3d. . .	56	5	0	
Weather-boarding. .	32,000 feet	at 0s. 1⅛d. . .	150	0	0	
			668	9	3	or £167 2s. 3¾d. per stable.

Total per stable £196 18s. 7d., or £1 19s. 4¾d. per horse.

LONSDALE A. HALE, LIEUT. ROYAL ENGINEERS.

January 20th, 1857.

TEMPORARY CAVALRY

CONSTRUCTED AT

ALDERSH

REFERENCES.

a. *Central upright 17'.6" × 8" diam.r*
b. *Outer .... d.o .... 9'.6" × 6" diam.r*
c. *Struts, 9'.0" × 4" diam.r*
d. *Pickets, 3'.6" × 3" diam.r*
f. *Inner rope-rafter.*
h. *Block carrying dripboard.*
g. *Points of connection of outer rope-rafters, shewn by dotted lines.*
e. *Weather-boarding*

FIG. 5.

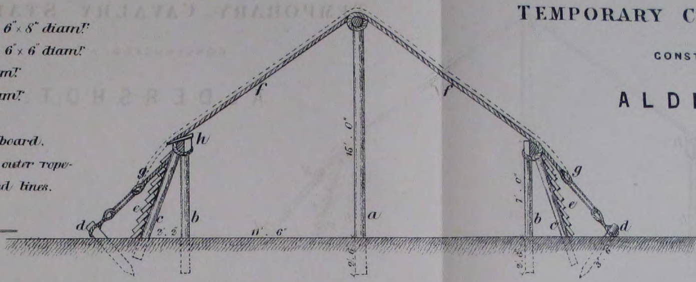


FIG. 1.

PLAN OF THE END OF A STABLE BUILT WITH WOODEN RAFTERS.

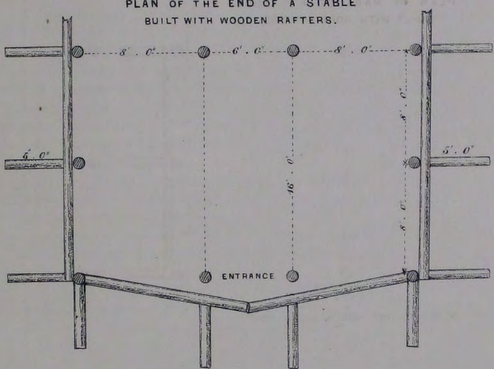
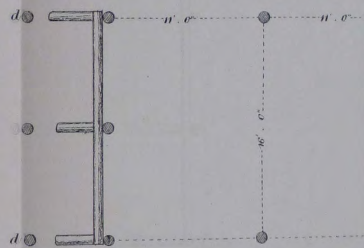


FIG. 3.

PLAN OF PART OF A STABLE BUILT WITH ROPE RAFTERS.



N. B. The end rafters are of wood.

FIG. 2.

SECTION OF STABLE SHEWN IN FIG. 1.

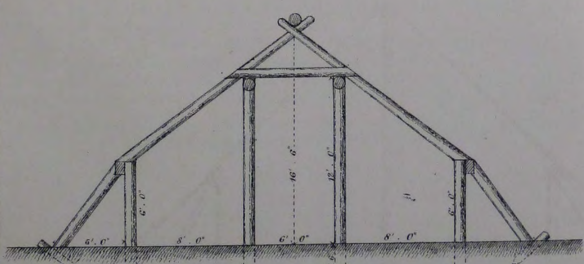
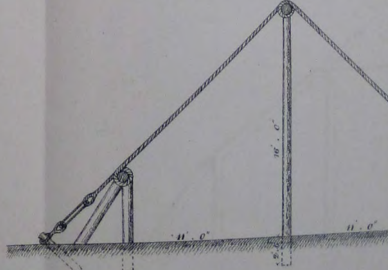


FIG. 4.

SECTION OF STABLE SHEWN IN FI



SCALE $\frac{1}{120}$.

PAPER XIII.

Report on the Operations Connected with the Laying Down of the Atlantic Submarine Telegraph Cable in 1857,

By MAJOR DU CANE, Royal Engineers.

London, August 25th, 1857.

Sir,

In obedience to the orders contained in your letter to me of the 3rd instant,* I have the honor to submit to you the following Report on the recent operations connected with the Atlantic Submarine Telegraph Cable, 334 miles 800 fathoms (nautical) of which unfortunately parted in 2,000 fathoms, on the morning of the 11th instant, 264 nautical miles from Valentia, lat. 52° 33 N., long. 17° 24 W.

1. It may be advisable, however, before I enter upon these operations, to relate concisely the origin of the Atlantic Telegraph Company; and for information on this subject I am indebted to a publication issued by order of the Directors, entitled "The Atlantic Telegraph."

In April, 1854, the colonial government of Newfoundland passed an act incorporating a Company for the establishment of telegraphic communication between the Old World and the New, extending to the Company grants of land and subsidy, and conferring upon it "the exclusive right to land a telegraphic line upon the coast under its jurisdiction, extending over the entire length of Newfoundland and Labrador."

A charter of "similar tendency was next obtained from the government of Prince Edward's Island, and from the State of Maine," with authority for certain subsidiary operations in Canada, and a ratification and confirmation of the Company's rights from the government at home.

The company, now incorporated under the name of the "New York, Newfoundland, and London Telegraph Company," proceeded next to connect St. John's Newfoundland with the lines already in operation in the British North American Provinces and in the United States.

In the summer of last year, the vice-president of the Company (Cyrus W. Field, Esq.) came to England to effect such arrangements as might prove most conducive towards the undertaking of laying a submarine line of electric telegraph across the Atlantic, between Ireland and Newfoundland.

The result of this visit was the formation of the Atlantic Telegraph Company (£350,000 capital, £1,000 shares) in November last, and in the same month negociations were entered into with the governments of Great Britain and the United States, which issued to their agreeing to engage by contract of 25 years duration, to

* Major Du Cane was ordered to proceed to Valentia, in conjunction with Lieutenant-Colonel Biddulph, R.A., and afterwards joined the Expedition.—*Ed.*

pay to the company, up to the time when its dividend shall have reached 6 per cent, a subsidy of £14,000 a year, and of £10,000 a year subsequently, and to furnish certain assistance in laying the cable down, by granting the service of ships."

2. "Contracts were now made with the Gutta Percha Company to supply 2,500 miles of core, consisting of copper wire invested by a triple covering of the insulating substance at £40 per mile; and with Messrs. Newall and Co., of Birkenhead, and Messrs. Glasse, Elliot, and Co., of East Greenwich, respectively, for the supply of 1,250 miles of the completed cable, from each firm, for the sum of £62,000."

I forward with this Report specimens of the cable with which, however, you are probably familiar.

3. There are three essential conditions in the manufacture of a submarine cable, which, in the present undertaking, had to be most carefully fulfilled, viz., strength, flexibility, and lightness; and after great consideration and numerous experiments the the following descriptions of submarine cable were adopted, and eventually manufactured.

No. 1—2,494 statute miles of cable known as "deep sea." No. 2—25 ditto of heavier cable for the shore ends, making a total of 2,519 statute miles.

No. 1, the deep sea cable, is composed of 1 strand of 7 copper wires of the purest copper, whilst the wires themselves consist of 1 straightly drawn, with the other 6 twisted round it, the copper strand thus formed measuring $\frac{1}{16}$ inch in diameter. The wire is No. 22 guage, coated with gutta percha, in 2 mile lengths, every length being carefully tested: indeed throughout the manufacture of a cable the testings are unceasing for strength, continuity, and insulation.

The conducting strand is covered with 3 "servings of gutta percha, which are in their turn enveloped in 5-thread yarn, composed of hemp and tar, the whole being surrounded with an iron casing composed of 18 strands of 7 twisted No. 22 charcoal-iron wires, making a cable of $\frac{4}{6}$-inch in diameter.

No. 2, or the shore cable, is composed of similar conducting wires, covered with an additional serving of gutta percha with a thicker coating of hemp and flax, and finally bound with a massive iron casing composed of 12 wires of No. 1 guage.

The annexed table will shew at a glance the conditions of the cable.

Description of Cable.	No. of Statute Miles.	Diameter of Cable.	Diameter of Conducting Wire.	Weight per Mile.	Expense per Mile.	Specific Gravity.	Remarks.
Deep Sea.	2,494	$\frac{4}{6}''$	$\frac{1}{16}$	about 19 cwt.	£100	about 2,952*	*2,972 by another observation. Breaking strain (from 3 tests) 4 tons
Shore.	25	$1\frac{5}{8}''$	$\frac{1}{16}$	about 8 tons	£300		

The portion of cable manufactured at Greenwich was commenced in February; the works at the manufactory were not however in full operation until March; the whole amount of the cable was finished in June. The Greenwich half of the cable was manufactured with its external wire laid in an opposite direction to that of the Birkenhead half.

The first idea entertained in the construction of the Atlantic Cable was that of using steel for the outer covering, instead of charcoal-iron, as previously described; this idea was however subsequently abandoned, owing to the additional expense involved by the adoption of steel, the increase of weight, and the limited supply of the material at hand, the greater strength of the steel over the iron cable not affording a sufficient compensation for the increase of expense.

An examination of the deep sea cable will at once shew its great strength, remarkable flexibility, and beautiful manufacture.

For the foregoing information I am indebted to Mr. Glasse, of the firm of Glasse, Elliot, and Co., East Greenwich.

Perhaps I cannot conclude this section of my report more appropriately than by inserting the requirements of the cable from the pamphlet on the "Atlantic Telegraph" previously quoted.

"The cable required to be a rope weighing a ton per mile, of such size that it was just so much heavier than the water it displaced in sinking as to be carried quickly through the liquid to the bottom, of the greatest strength that could be communicated to it under these circumstances, and of such structure that it could be readily bent and yet be able to lie in a sufficiently rigid line.

"Its centre required to be composed of a wire capable of being made to convey electric signals through an extent of more than 2,000 miles, and capable of retaining complete insulation when immersed in the water of the sea."

4. In accordance with the agreement entered into with the Atlantic Telegraph Company, by the English and American governments, the Agamemnon, 91 guns, (screw) English, and the Niagara steam frigate (screw), American, were selected to receive on board of them the Atlantic Cable.

Accordingly, in June, the Agamemnon proceeded to Greenwich, and was moored off the works of Messrs. Glasse, Elliot, and Co. The Niagara steamed to Birkenhead, after having undergone at Portsmouth some alterations in her interior in order to receive her portion of cable.

The hold of the Agamemnon being sufficiently large, the whole of the Greenwich portion of the cable was stowed round a central core in the hold of the ship, into which it was conducted from the Greenwich works by means of a small steam engine of 12-horse power, the cable itself being passed over sheaves attached to the masts of two or three barges, forming a line of communication between the manufactory and the ship.

The time occupied in coiling the Greenwich half of the cable on board the Agamemnon was about a month or five weeks, at the rate of between 50 and 60 miles per diem, night and day.

The number of men so employed was about 20 from the manufactory and an equal number from the sailors of the Agamemnon, a certain number of whom it was most desirable to have instructed. The whole operation was performed by hand, the men being employed in watches.*

The mass of cable, when coiled, consisted of about 234 layers, rising 11′ 6″ above the bottom of the ship's hold. The arrangement of the coil was somewhat elliptical, the longer diameter being fore and aft.

The lowest layer measured about 44 feet in length by about 28 feet in breadth, and rested on a platform of 3-inch plank, flush with the upper part of the keelson. The upper layer of cable was about 50 feet in length by 44 feet in breadth. The first five lower layers measured 14½ miles, whilst the length of the upper one alone was 6 miles. The shore cable was stowed on the orlop deck of the Agamemnon. With this great mass of cable, it is scarcely necessary to remark that very great care was requisite to coil it so as to prevent the slightest "kink" in the paying out.

* I may mention that 20 expert men alone would have been quite sufficient (in watches); the addition to the number arose from the crew having to be instructed in coiling.

The Niagara not possessing the same capability for receiving her portion of the cable in one place as the Agamemnon, had it distributed as follows:—

On upper deck.	130	statute miles.
On main "	294	"
On lower "	182	"
On " hold.	352	"
On portion of ward room. . . .	297	"
Total. . . .	1,255	"
and heavy shore end.	10	"

making in all 1,265 statute miles.

The cable on board the Niagara was coiled in circles around wooden cores.

The time occupied in coiling the 1,255 miles of small or deep sea cable on board the Niagara was 20 days and 10 hours: average per hour—2 $\frac{56}{100}$ miles.

5. The ends of the coils to be paid out were, on board each ship, run over a succession of wooden circular sheaves, and so conducted to the paying-out machine, patented by Messrs. Bright and De Bergue, and constructed expressly for this Expedition at a cost of £3,000 for the two machines, the weight of each of which averaged about 15 tons.

I very much regret that no finished plans of these machines have as yet been issued, therefore I am unable to annex drawings of them to this Report as I had hoped to have done. I will however endeavour to explain briefly the principles of their construction and action. The paying-out machine consists of four large iron sheaves or drums (vertical), the two central sheaves having two grooves, with flanges of sufficient size and depth to fit and retain the cable. The two outer sheaves have only a single groove, but are nevertheless of the same thickness as the two central ones. The central sheaves are elevated above the outer ones, in order to allow the cable free ingress and egress from the hold to the stern of the ship, by preventing its coming in contact with the tops of the two single sheaves. The two double sheaves were used for the deep sea cable, which, having to sink to great depths, was supposed to require a greater restraining power than the shore part, which passed over the two single sheaves and only one of the grooves of the two double-grooved sheaves. The four sheaves were 5 feet in diameter and 3¾ inches thick, and the depth of the grooves was 2 feet 4 in.

Between the two central sheaves was a break, so connected with the former as to revolve at three times their speed. This break, or friction wheel, 2 feet in diameter, was in its turn regulated by two massive wooden "breaks" 3 feet long, closed to or opened out from each other by an iron bolt, worked by toothed wheels in connection with a screw and handle, so that at any moment the restraining power on the whole machine might be regulated by turning the screw handle.

The sheaves themselves were turned by toothed wheels of equal diameter revolving on the same axis, and connected with the friction wheel previously described, the whole being again moved and reversed (if required) by a wheel moved by a steam engine of about 15 horse power, which, in the Agamemnon, was on the main, and in the Niagara on the quarter-deck. The cable passed from the hold of the ship over a series of wooden drums or sheaves, then through the paying-out machine, and thence over the poop of each vessel to an iron stern-wheel, over which it passed into the sea. This wheel was partially encased by a deep flange or guard to prevent the cable from being jerked out of the groove. The groove itself was made so as to form a bed for each description of cable.

The stern-wheel on board of the Niagara was situated on the starboard side of the stern, and was, I believe, similarly situated in the Agamemnon. The wheel itself was held in position by a strong massive wooden girder extending from the after part of the quarter-deck; its revolution was performed by the cables paying out, and formed an index of the cable's rate of motion. To the paying-out machine were attached two indices, one exhibiting the strain on the cable when passing out, the other the number of miles of cable paid out.

I should mention that each machine was provided with duplicate stores of breaks, &c. There was also on board each ship a *winding-up machine*, consisting of a series of vertical drums: they were however never employed. Each ship was furnished with buoys for buoying the cable.

The propeller of the Niagara was protected by an open iron casing, extending from the lower portion of the stern outside the rudder, and so downwards.

The steam engine used was considered auxiliary, for the machine when once in motion was intended to revolve without any steam power.

Both vessels were fitted with fore as well as stern wheels, in order that if a gale should blow from the eastward, during the operation of laying down, the paying-out ship might round to, head to wind, and the cable be brought over the fore instead of the stern wheel, and so avoid the danger arising from the ship's being driven back upon the cable, or the cables fouling against the ships' stern. This expedient was however never resorted to.

6. I will reserve my description of the electrical apparatus for another part of this Report, and will proceed to describe the position marked out for the cable across the Atlantic, and the plans proposed and eventually adopted for laying it down.

The shortest distance across the Atlantic, between Europe and the Continent of America, is from the Western Coast of Ireland to the Eastern Coast of Newfoundland, a distance of between 1,600 and 1,700 nautical miles. But in deciding on the line between any two given points, there arises the important question—whether that line can be made available for the purpose intended? In the case of uniting Ireland and America, there arose questions of the nature of the ocean's bed throughout the line proposed, the influence of drifts and currents during the process of submerging the cable, the prevalence of gales, storms, ice, and fogs. These enquiries had to be solved satisfactorily before either Valentia Bay in Kerry, or Trinity Bay in Newfoundland, could be selected as termini for an Atlantic cable. "In its entire length," says Lieutenant Maury, U.S.N., "the basin of the Atlantic is a long trough separating the Old World from the New, and extending probably from pole to pole. From the top of Chimborazo to the bottom of the Atlantic, at the deepest place yet reached by the plummet in the North Atlantic, the distance in a vertical line is nine miles."

"There is, however," adds Lieutenant Maury, "at the bottom of this sea, between Cape Race in Newfoundland, and Cape Clear in Ireland, a remarkable steppe which is already known as the 'telegraph plateau,' varying in depth, as shewn by soundings, from 1,750 fathoms (on the Irish side of the Atlantic) to 1,950, 2,290, and 2,424 fathoms (maximum), and rising gradually to 1,515 and 1,495 fathoms, until the more shallow water is reached."

The specimens of the bottom of this plateau, which have been brought up, consist for the most part of apparently white sandy matter, which, on microscopic examination, has been proved to be of a shelly nature. "The ocean's bed," says Maury, "has been found everywhere, wherever Brook's sounding rod has touched, to be soft, consisting almost entirely of the remains of infusoria. The gulf stream has literally strewed the bottom of the Atlantic with these microscopic shells." In such a bed as this, exposed to no disturbing action of the sea above, a submarine cable might lie without danger of abrasion, whilst the tar of the cable, which is always pressed out during the process of submersion, would take up this shelly matter, and thus the cable would receive an additional protecting coat from the ocean's bed.

On the prevalence of gales, ice, and fogs over the plateau, Lieutenant Maury was consulted; and his letter to Cyrus W. Field, Esq., I beg to annex to this Report (lettered B). It is one of considerable interest and material value. Lieutenant Maury, after drawing up a route for the paying-out vessels, making a distance from Valentia to Trinity Bay of 1,635·1 nautical miles, weighs previous records of fogs, gales, and ice during various months of successive years, recommends the two steamers "not to join cables until after the 20th July, and concludes by saying, "I think between that time and the 10th August the state of both sea and air is usually in the most favorable condition possible, and that is the time which my investigations indicate as the most favorable for laying down the wire."

To conclude the subject of the proposed route for the Atlantic cable, I should add that Valentia Bay, on the Western Coast of Kerry, was selected, from its being the most westerly portion of Ireland, from its possessing deep water, and not being much used by vessels for anchorage.

The project first entertained for laying down the cable itself was that each ship should, after receiving on board her half of the cable, make for Queenstown, near Cork, and afterwards that both should steam to mid-ocean, lat. 52° 49′, long. 32° 32′, central distance 817·5 miles, where they should splice the ends of their respective cables, and then steam eastward and westward, one to Valentia, and the other to Trinity Bay.

Through the kindness of the Company's Chief Engineer (Charles Bright, Esq.,) I am enabled to forward with this Report the opinions (lettered C) expressed by naval and other scientific men on this, or the mid-ocean project, and the other, or "shore plan," which was subsequently adopted.

The shore plan was simply to pay out the cable from shore to shore, splicing the ends of the portions carried by each ship in mid-ocean. The reasons urged for and against are of an interesting nature, and I should observe that the Chief Engineer (Mr. Bright) expressed himself strongly in favor of the mid-ocean plan, as also Capt Wainwright, of the Leopard. Master Commander Noddall, R.N., of the Agamemnon, after writing in favor of the shore plan, subscribed to the other, out of deference to the engineers employed; whilst Professor Morse, consulting electrician to the Company, after supporting the mid-ocean project, on due reflection advocated strongly the shore plan, in which he was supported by Mr. W. Whitehouse, the electrician to the company.

Reference to the letters of these gentlemen will shew that whilst the engineers viewed the mid-ocean plan as the easier for overcoming the difficulties belonging to their own department, the electricians inclined to the shore plan, regarding the mid-ocean plan as one calculated seriously to augment electrical difficulties and chances of failure.

It was finally resolved that the Niagara should land the end of her portion of cable on the shore of Valentia Bay, and then commence paying out to mid-ocean.

7. I now approach the brief operations in connection with the actual laying down of the cable itself. Her Majesty's steamers Leopard, Captain J. F. B. Wainwright, R.N., and Cyclops, Lieutenant Commander Dayman, R.N., were ordered to join the expedition, in connection with the United States steam frigate Susquehanna, Capt. Sands, U.S.N. The command of the English portion of the squadron devolved on Captain Wainwright, R.N.

These additional steamers were sent to render assistance (if required) to the paying-out vessels. The government tender Advice* also came round from Queenstown and was placed at the disposal of the Directors of the Company. The squadron met at Queenstown towards the end of July, and remained there for several days, during which time some very interesting experiments were made on the cable by the electricians.

At 5 P.M., August 3rd, the Niagara got up steam and stood out of Queenstown harbour, the Leopard, Susquehanna, and Agamemnon leading the way, and on the following day the ships arrived off Valentia, the Niagara at 12·30 P.M., anchoring two miles from the place for landing the cable.

On the 5th, at 1·11 P.M., the Niagara commenced paying out the heavy shore end of the cable on board the paddle-box boats of the Leopard, the boats of the Susquehanna, and "Willing-mind," a hired steam-tug, and at 7·30 P.M., the tug slowly steamed into the bay with the boats in tow, and having the end of the cable on board.

The place selected for the landing was favorable. The shore end was landed at the head of the bay at about 7·30 P.M., and laid in a trench previously excavated. It was laid with all ceremony in the presence of the Lord Lieutenant of Ireland and numerous spectators.

At 8·10 P.M., the first communication from the shore was sent through the shore end and deck coil of the cable.

The total length of cable run out on the occasion of the landing measured 2,040 fathoms.

On the following morning, the 6th instant, at 5 A.M., the Niagara weighed anchor with fine weather, wind W.

I am indebted to Charles Bright Esq., (Chief Engineer) for kindly placing his log at my disposal, from which the following account of the laying down is taken.

At 6·15, "whilst fitting a guard" above the first sheave, the cable slipt off the machine, and soon after parted, on a sudden lurch of the ship occurring. It appeared, from the rigidity of its hold upon the bottom, to be caught by a rock. The cable was then grappled for, but without success, and in consequence was obliged to be under-run from the shore by the Willing-mind tug and boat's crew from the Susquehanna (the Leopard steaming off and on to assist). The weather was too rough to splice, so the Niagara anchored, and the cable was buoyed. On the following morning, the 7th instant, the wind being from the north-west, accompanied by squalls, the splice could not be effected before 3 P.M. The cable was again under-run and signals passed through satisfactorily to and from the shore. At 6 P.M. the splice was completed and all necessary preparations were made; the Niagara got under weigh at 7 P.M. and commenced paying out.

The Agamemnon, during this time, stood off and on; the Leopard had anchored in the bay, as also the Cyclops.

By 7·30 P.M., all the ships were under weigh and making their respective courses, the Leopard remaining for the most part, until the parting of the cable, on the port, and the Susquehanna on the starboard quarter of the Niagara.

At 9·30 P.M., the rate of the cable was 2 knots; total laid, 6 miles; wind moderate; N. W. bar, 29 90. The end of the heavy cable being near, a 7 ft. buoy was attached to it.

11·20 P.M., total cable laid 8 miles, ship being in 43 fathoms of water, and having run out the shore end of the heavy cable, came to the tapering joint, secured the end of the heavy cable with a 5-inch hawser to lower it by; the joint proved faulty and sprung in the machine; renewed the splice, bridled it, sent on an additional hawser to the former one, and lowered it by the hawsers until it reached the bottom. The hawser was then cut, and the paying out of the small (or deep sea) cable commenced.

* After the squadron sailed from Valentia the Advice returned to Queenstown.

By noon the following day, the 8th instant, 40 miles* 460 fathoms (nautical) of the cable had been paid out, whilst 37 miles had been actually made good, to which must be added 2 miles for anchorage to shore.

Up to this time the maximum rate of ship attained had been 3 miles 800 fathoms per hour; that of cable 4 knots, and average about 3·250. The excess of cable over distance was 3 miles 460 fathoms.

At 1 P.M. a want of communication with the shore was reported, but was made good at 3·30 P.M. The strain of the cable during this time amounted to 5 cwt.; but at 5 P.M., when 58 miles 950 fathoms of cable had been laid, the speed of the cable increasing over that of the ship, 1 cwt. additional strain was applied.

At 8·30, want of continuity again reported, the ship was stopped, but soon after the continuity was reported as re-established.

At 1 A.M., on the 9th (Sunday), the rate of the ship being 2 miles 200 fathoms, and that of the cable 4·958 (more than double) the strain was increased from 6 to 7 cwt.; and at 7·30 A.M. all the deck coil being paid out, the rate of the ship was decreased for a few minutes, when the bight of the cable was passed and the paying out of the upper coil forward was commenced.

By noon 64 miles had been made good by the Niagara since noon previous.

Total distance.	103 miles.
Cable paid out.	136 „ 300 fathoms.
Excess.	33 „ 300 fathoms.
Average rate of paying out. .	. from 3 to 4 knots.

At 12·40, P.M., want of continuity reported, but only for 15 minutes; again reported at 1·35, but re-established at 2 P.M., when the rate of ship was decreased, to be increased again at 6 P.M., for it became apparent to every one that the rate of the cable surpassed that of the ship in so large a proportion, as, at that rate, to endanger the amount of spare cable supplied being sufficient.

From this time the average rate of the ship maintained until 2 A.M. on the 10th instant was 5 knots, which reduced the rate of the cable.

At 3 A.M., passed in 8 miles from 580 or 600 fathoms to 1,753 fathoms.

At 6 A.M., no communication with the shore reported; then occasional weak currents only; re-established at 8 A.M.

Amount of cable to noon 10th. . .	254 miles 850 fathoms.
Distance made good. . . .	214 „
Excess.	40 „ 850 „
Wind.	W. by S.
Barometer.	29·60
Course.	N.W. by W.½W.

At 1 P.M., course altered to W.N.W., rate of ship varied until midnight from 3 to 4 and 5 knots, that of cable averaging from 5 to 6 ditto, but the restraining power on the cable, owing to the pressure arising from the deep water the ship was passing over, was considerably increased, until at 1 P.M. it attained to 19 cwt., and at 6 P.M. to 1 ton. At 6 P.M., the cable slipt off the sheaves, from the tar of the cable hardening and filling up the grooves of the sheaves: this was subsequently rectified. The same difficulty occurred again at 9 P.M., the sheaves were oiled and additional guards fixed. Course of ship N.W. by W.½W. The restraining power was also increased to 25 cwt. At midnight 316 miles of cable had been paid out.

At 11 P.M., want of continuity was reported, but re-established at 11·25. The egress of the cable still increased. "At 1 A.M., on the 11th instant, while the vessel was making

* The miles mentioned hereafter are nautical.

only 3 knots per hour, a retarding force equal to a ton (which had previously been sufficient to keep the rate of egress of the cable near enough to that of the ship) allowed it to run out at a speed of between 5 and 6 and sometimes even 7 knots per hour, the strain was therefore gradually raised to 30 cwt., and then again to 35 cwt., in consequence of the speed continuing to be more than would have been prudent to permit." "By this time the rate of the cable was brought to a little short of 5 knots, at which it continued steadily until, either by an excessive pitch of the ship or by taking hold of the bottom, it suddenly broke asunder." The Chief Engineer also considers that there was a want of attention to the breaks on the part of a mechanic in charge. The wind at this time was from W.N.W., accompanied by swell, which increased before noon and moderated before night. Soundings were taken by the Cyclops near where the cable parted, and found to be 2,000 fathoms. Amount of cable run out, 334 miles 800 fathoms, 264 miles from Valentia, lat. 52° 33′ N., long. 17° 24′ W.; barometer, 29·75.

The accident was much to be regretted, for the weather had been throughout most favorable, barometer steady, wind and sea moderate; whilst for 12 hours previously the cable had been paying out successfully in soundings varying from 1,700 to 2,000 fathoms.

The revolutions of the stern-wheel showed from time to time the rate of the cable in leaving the ship: its general angle with the horizon was about 15°, but occasionally when under great strain the angle was increased.

In consequence of the parting, the Expedition terminated. The Leopard returned to Spithead and the Cyclops to Valentia, leaving the Agamemnon and Niagara to make some experiments, a list of which is annexed.

1. Splice cable, as was at first intended, in the middle, and each ship pay out 5 miles.
2. Each ship to wind up, with the machinery on board, the above amount of cable.
3. Splice cable the same as we should have done if we had gone on paying out to the centre successfully and if no accident had occurred.
4. Cyclops to take soundings here. (This was done—2,000 fathoms.)
5. Ascertain current here, upper and lower—(Could not be ascertained for swell.)
6. The cable on board the two ships being twisted differently, the splicing together and paying out will test whether they can be spliced and paid out successfully or not without untwisting.
7. Ascertain by test if the large buoy will support the cable in deep water.

I will now offer a few remarks on the electrical instruments employed for the transmission of the current through this great extent of wire.

It is well known that submarine cables, after immersion, assume the electrical conditions of Leyden Jars, differing entirely from overground conducting wires, where the retardation of the electric current is inappreciable for hundreds of miles. Submarine cables, however, as they lie beneath the surface of the water, suffer from the influence of electrical induction which acts as a retarding power to a considerable extent. As soon as this fact was fully established, it became a matter of considerable moment to ascertain how far the obstacles caused by induction could be met and overcome. After numerous experiments undertaken by Messrs. Bright and Whitehouse (at some of which Professor Morse was present) the following conclusions were arrived at:—*

1. "That gutta percha covered submarine wires do not transmit as simple insulated conductors, but that they have to be charged as Leyden Jars before they can transmit at all.

2. That consequently such wires transmit with a velocity which is in no degree in accordance with the movement of the electrical current in an unembarrassed way along simple conductors.

* See the pamphlet on the Atlantic Telegraph.

3. That magneto-electric currents travel more quickly along such wires than simple voltaic currents.

4. That magneto-electric currents travel more quickly when in high energy than when in low, although voltaic currents of great intensity do not travel more quickly than voltaic currents of small intensity.

5. That the velocity of the transmission of signals along insulated submerged wires can be enormously increased, from the rate indeed of one in two seconds to the rate of eight in a single second, by making each alternate signal with a current of different quality, positive following negative, and negative following positive.

6. That the diminution of the velocity of the transmission of magneto-electric currents, in induction-embarrassed coated wires, is not in the inverse ratio of the squares of the distances traversed, but much more nearly in the ratio of simple arithmetical progression.

7. That several distinct waves of electricity may be travelling along different parts of a long wire simultaneously, and, within certain limits, without interference.

8. That large coated wires, used beneath the water or the earth, are worse conductors, as far as velocity of transmission is concerned, than small ones, and therefore are not so well suited as small ones for the purposes of submarine transmission of telegraphic signals, and

9. That by the use of comparatively small coated wires, and of electro magnetic induction coils for the exciting agents, telegraphic signals can be transmitted through two thousand miles with a speed amply sufficient for all commercial and economical purposes.

These conclusions have been inserted, not only because they are interesting in themselves, but because it was upon these data that the electricians arranged their apparatus for electrical transmission. It must not however be supposed from the foregoing remarks, in which electro-magnetic agency is so strongly advocated, that voltaic action is entirely dispensed with; the voltaic battery is the primary source of the electrical action, which, by an electro-magnetic process, becomes the transmitting current along the line of submarine wire.

The voltaic batteries (Whitehouse's) employed consist each of 10 platinized silver plates, and 10 zinc ditto, arranged alternately from zinc to silver: although alternate in their arrangement they are not connected together by pairs (*i. e.* zinc and silver); on the contrary, the zinc plates, which, like the silver, slide into grooves made in a gutta percha trough encased in another of wood 1′ thick, rest on a horizontal plate or bar of the same metal, about 2 inches broad, whilst the silver plates of the battery are connected together at top by a brass frame $1\frac{1}{4}'' \times \frac{1}{2}''$. Thus all the zinc plates are connected together by the horizontal zinc plate below, whilst the silver are united by the metallic frame above, and there clamped by the usual clamp screws, a simple and useful arrangement. The acid (sulphuric, 1 in 15,) of course flows between the cells in the usual way.

The dimensions of the voltaic battery were as follows: —

Size of trough.	$22'' \times 15'' \times 12''$.
Brass frame of silver plate. . .	$22'' \times 1\frac{1}{4}'' \times \frac{1}{2}''$.
Zinc rod of zinc plates. . . .	$2''$ broad.

Size of silver plate . . }
Size of zinc ditto . . } . about 10 square inches. Price of silver £5 per plate.

It will thus be seen, from the dimensions given, that the sizes of the battery plates are very considerable, and as the quantity of electricity circulated by a voltaic arrangement depends upon the size employed, from plates of these dimensions, covering quite 2,000 square inches, electricity of quantity would be generated to a very large amount.

Although each battery is provided with 20 cells of zinc and silver together, yet not more than 15 were used, a central space of 5 grooves being left to promote the circulation of the fluid, 20 of these batteries were supplied to each ship, making 40 in all.

The great advantage derived from this voltaic arrangement is that of allowing the withdrawal of plates at pleasure without arresting chemical and electrical action.

Fifteen batteries were used for the whole circuit, and thus formed the primary source of the electric fluid. When in action the heat generated was very considerable, so much so as not only to waste the metal of the battery terminals but also the contact key of the telegraph instrument, by which the signals were made. The latter evil was however materially obviated by exposing to the action of the current a large surface of metal, by which $\frac{4}{5}$ of the electric spark was destroyed, the surface exposed dispersing the effect.

It has been before stated that the electro-magnetic action on a submarine cable (especially of great extent like the Atlantic one) is far more efficacious than immediate voltaic action. A great quantity of electricity having been generated from the batteries described, it was necessary, in order to send currents of sufficient power through the wire, to increase the electrical intensity. And the magneto-electric influence was put in force by an apparatus consisting of two double induction coils arranged as follows.

They are each composed of an iron core 4″ in diameter and 5 feet long, which core is afterwards wound with 5 miles of fine silk-covered copper wire (about 20 guage) and surrounded by gutta percha.

The core so enveloped is now encircled very closely by copper wire, of 14 guage (cotton covered) around which is spread a second coating of gutta percha. The larger wire is called the quantity, primary inducing, or generating coil. The smaller is the intensity, secondary passive (or to be excited) coil. The former is connected with the battery, the latter with the line and earth wires.

The electricity generated by the voltaic battery, on contact being made by the contact key, flowing through the "generating or quantity coil," converts, by a well-known electrical property, the soft iron bar within, into a powerful electro-magnet, which, in its turn, excites the intensity or secondary coil, and that most powerfully, resembling in its effects (although they are not so intense) those produced by a Rhumkhorff coil.

The intensity coil being in connection (as I have before stated) with the line and earth wires, was designed to throw this powerful induced current throughout the whole extent of cable, when laid down. It was intended also to use a relay battery in connection with the line, and Morse's printing instruments, from which the printed pages would have been wound off.

I ought, before concluding this subject, to state how the "earth" connection was made during the operations. That on land was made by the iron of the shore wire being buried in the earth. On board the Niagara the conducting wire was attached—1. To the lightning conductor of the ship; 2, to the propeller; 3, to the iron of the cable itself, forming three earth connections.

I conclude this Report with a few reflections which naturally arise from the undertaking.

1. Without wishing to criticise unduly the operations in question, I think it is a matter for regret that the Company did not, before attempting to lay the cable, gradually secure their ground by availing themselves of some favorable opportunity for making the very experiments tried on the morning of the 11th August.

This preliminary step would have most probably reduced an uncertainty to a comparative certainty, and would have thrown considerable light on the feasibility of the two plans proposed for establishing the cable. It would also (as far as we can discern) have given their engineers experience in the relative merits and defects of their paying-out machinery, and of the dangers which have to be met and overcome in submerging cables at such great depths as those successfully reached.

2. I would suggest, in the event of the government undertaking at any future time to establish a line of submarine telegraph, that they should always connect with the undertaking an experienced officer of the Navy.

3. All unnecessary splicings of cables, especially at sea, should be avoided, since they are invariably fraught with danger, and the necessity for shore ends should be carefully considered, involving, as they do, a splice generally made at sea and attended with risk.

4. Paying-out machinery should be of a very simple description, and the sheaves employed should be provided with deep flanges and sufficient guards, so as to offer a secure bed to the cable whilst paying out.

The tar and pitch of the cable often hardened in the grooves of the sheaves, and of course retarded the paying out. The grooves had to be frequently moistened with oil to soften the tar, whilst additional guards had to be fixed to the sheaves.

5. When deep soundings are to be reached, these operations have shewn the necessity for having a very considerable amount of extra cable; the greater its amount the less necessity is there for placing any heavy restraining power on the submerging cable; and the less also are the chances of rupture, the greater therefore the eventual economy.

6. A medium speed of ship is better and safer for paying out than one too slow, or again one too fast: perhaps 5 or 6 knots per hour is safest. The rate of the cable in paying out is sure to exceed the rate of the ship, to meet which it is better to increase the speed of the ship than to reduce the rate of the cable by great restraining power.

7. I would recommend paddle steamers with low sterns, rather than screw-ships, the motion of the former being much less, whilst a low stern tends to relieve the strain of the cable.

I beg to express to you my sense of the kindness I experienced from the Company's officers and from other gentlemen engaged in this undertaking.

I have the honor to remain,

SIR,

Your most obedient servant,

(Signed) F. DU CANE,

Captain Royal Engineers and Major.

PAPER XIV.

ON THE FIGURE, DIMENSIONS, AND MEAN SPECIFIC GRAVITY OF THE EARTH, AS DERIVED FROM THE ORDNANCE TRIGONOMETRICAL SURVEY OF GREAT BRITAIN AND IRELAND.

COMMUNICATED TO THE ROYAL SOCIETY

BY COLONEL JAMES, R.E., F.R.S., &c., SUPERINTENDENT OF THE ORDNANCE SURVEY.

The Trigonometrical Survey of the United Kingdom commenced in the year 1784, under the immediate auspices of the Royal Society; the first base was traced by General Roy, of the Royal Engineers, on the 16th of April of that year, on Hounslow Heath, in presence of Sir Joseph Banks, the then President of the Society, and some of its most distinguished Fellows.

The principal object which the government had then in view, was the connexion of the observatories of Paris and Greenwich by means of a triangulation, for the purpose of determining the difference of longitude between the two observatories.

A detailed account of the operations then carried on is given in the first volume of the 'Trigonometrical Survey,' which is a revised account of that which was first published in the 'Philosophical Transactions' for 1785 and three following years.

At the time when these operations were in progress, the survey of several counties in the south-east of England, including Kent, Sussex, Surrey, and Hampshire, was also in progress, under the direction of the Master-General of the Ordnance, for the purpose of making military maps of the most important parts of the kingdom in a military point of view; and it was then decided to make the triangulation which extended from Hounslow to Dover the basis of a triangulation for these surveys.

It is extremely to be regretted that a more enlarged view of the subject had not then been taken, and a proper geometrical projection made for the map of the whole kingdom. As it is, the south-eastern counties were first drawn and published in reference to the meridian of Greenwich, then Devonshire in reference to the meridian of Butterton in that county, and thirdly the northern counties in reference to the meridian of Delamere in Cheshire; but there is a large intermediate space, the maps of which are made of various sizes to accommodate them to the convergence of the meridian.

In 1799 the Royal Society gave further proof of the interest it took in the progress of the survey, by lending to the Ordnance its great 3-foot theodolite, made by Ramsden, for the purpose of expediting the work of the survey; and I have great pleasure in stating, that although this instrument has been in almost constant use for the last sixty-seven years, during which time it has been placed on the highest church towers and the loftiest mountains in the kingdom, from the Shetlands to the Scilly Islands, it is at this day in perfect working order, and probably one of the very best instruments that was ever made.

The great trigonometrical operations of the survey have been carried on under so many officers, from the time of their commencement under General Roy down to the present time, that it would be quite impossible, in this short notice, to mention more than the names of several Superintendents who have succeeded General Roy, viz., Colonel Williams, Major-General Mudge, Major-General Colby, and Colonel Hall; but in justice to the highly meritorious body of non-commissioned officers of the corps of Royal Sappers and Miners, I should state, that whilst in the early part of the survey the most important and delicate observations were entrusted solely to the commissioned officers, those duties have of late years been performed by the non-commissioned officers with the greatest skill and accuracy.

In the historical sketch of the survey which I purpose publishing shortly, I hope to be able to do justice to the individual merits of all employed.

The computations connected with the corrections of the observed angles, to make the whole triangulation as nearly as possible perfectly consistent, have been most voluminous, and have been made under the direction of Lieut.-Colonel Yolland, Captain Cameron, and Captain Alexander R. Clarke; but I gladly avail myself of this opportunity to acknowledge the great and important assistance and advice which, both as regards the instruments and the calculations, we have at all times received from the Astronomer Royal.

The triangulation, by the methods which will be explained, is now made consistent in every part, so that any side of any triangle being taken as a base, the same distance will be reproduced when it is computed through any portion or the whole series of triangles; and when the five measured bases on which we rely are incorporated in this triangulation, the greatest difference between their measured and computed lengths is not as much as 3 inches, and yet some of the bases are upwards of 400 miles apart.

Several bases of from five to seven miles long have been measured, but those upon which the chief reliance has been placed are the Lough Foyle and Salisbury Plain bases, which were measured with General Colby's compensation bars. The difference between the measured and computed length of the one base from the other, through the triangulation, is 0·4178 ft. or about 5 inches.

This difference has been divided in proportion to the square root of the lengths of the measured bases, by which we have obtained the mean base which has been used in the triangulation; there is therefore a difference of + or −0·2 ft., or 2½ inches between the measured and computed lengths of these bases from the mean base.

The Hounslow Heath base was measured with Ramsden's 100-feet steel chains, and only differs 0·173 feet, or about 2 inches, from its computed length from the mean base.

The Belhelvie base in Aberdeenshire, also measured with the steel chains, differs only 0·24 feet, or less than 3 inches, from the computed length.

The difference between the measured and computed length of the Misterton Carr base, near Doncaster, also measured with the steel chains, is only 0·191 feet, or about 2 inches; and it will be observed that the difference between the computed and measured lengths of these three bases (measured with chains) is not greater than the difference between the measured and computed length of the Lough Foyle and Salisbury Plain bases (measured with the compensation bars), from which it may be inferred that bases measured with steel chains are deserving of the greatest confidence; and when the great simplicity, portability, and cheapness of the chains is compared with the complex, heavy and expensive apparatus of the compensation bars, I should anticipate that they would be more generally employed than they have been of late years, especially in the colonies, and in countries where the transport of heavy articles is effected with difficulty.

The length of the base on Rhuddlan Marsh in North Wales, which was measured with steel chains, differs 1·596 feet from the computed length; but from the circumstance that the extremities of the base are very badly situated with reference to the surrounding trigonometrical stations, the angles being very acute, and not well observed, we have placed little confidence in the result of the comparison of its computed and measured lengths.

One of the first practical results arising from the completion of the triangulation is, that we are now able to engrave the latitude and longitude on the marginal lines of the old sheets of the 1-inch map of England, and this is now being done.

The following account of the trigonometrical operations and calculations has been drawn up by Captain R. Clarke, R.E.; this account may be considered as an abridgement of that more detailed account which is now in the press, and will be shortly published.

It will be seen that the equatorial diameter of the earth, as derived from the Ordnance survey, is 7926·610 miles, or about one mile greater than it is given by the Astronomer Royal in his 'Figure of the Earth,' and that the ellipticity is $\frac{1}{299,33}$, or as the Astronomer Royal conjectured, something "greater than $\frac{1}{300}$," which he gives in the same paper.

The mean specific gravity of the earth, as derived from the observations at Arthur's Seat, was stated in a former paper to be 5·14; the calculations have since been revised, and we now find it to be 5·316.

The mean specific gravity of the earth, as derived from the only other observations on the attraction of mountain masses on which any reliance has been placed, viz. the Schehallien observations, give, as finally corrected by Hutton, $\frac{99}{20}$, or almost 5·0.

From the experiments with balls we have the following results:—

By Cavendish, as corrected by Baily	5·448
By Baily	5·67
By Reich	5·44

From the pendulum experiments at a great depth and on the surface, the Astronomer Royal obtained 6·566.

I have recently received, through the Astronomer Royal, two copies of the new National Standard Yard: it is obviously necessary that our geodetic measures should be given in reference to the standard; but not knowing from what scale the standard has been taken, I am unable to say at present in what way the reduction is to be made; that is, whether by reference to the comparison of the old standards which have been already made, or by the mechanical process of a direct comparison of the Ordnance Standard with the new National Standard.

H. JAMES, Lieut. Colonel R.E.

The principal triangulation of the Ordnance survey of Great Britain and Ireland, extending from the Scilly Isles, in latitude 49° 53′, to the Shetland Isles, in latitude 60° 50′, and embracing at its widest extent about 12° of longitude, consists of about 250 stations.

The observations for the connection of the trigonometrical stations have been made with four large theodolites, two of 3 feet, one of 2 feet, and the other of 18 inches in diameter. The first two instruments (one of which is the property of the Royal Society), and the 18-inch theodolite, were constructed by Ramsden at the commencement of the trigonometrical operations in England in 1798: the 2-feet theodolite was constructed by Messrs. Troughton and Simms at the commencement of the Irish Survey in 1824.

The latitudes of thirty-two of the stations of the principal triangulation have been determined by observations made with Ramsden's zenith sector, and since the destruction of that instrument in the great fire at the Tower of London, with Airy's zenith sector. All the observations made with these instruments have been published in detail.*

The mode of observing with the theodolite may be shortly described as follows:— The instrument being first placed very carefully over the precise centre of the station, an object having a fine vertical line of light, with a breadth of about 10″, is set up in a convenient position within a mile or two of the station; this object, called the "referring-object," serves as a point of reference from which all angles are measured. The lower limb of the instrument being clamped, the observer intersects the referring-object and then each of the principal points in succession, concluding with a second observation of the referring-object, which should be identical, within the limits of errors of observation, with the first reading of that object: the instrument is then unclamped and the bearings read again on different parts of the divided circle. The method by which these observations are reduced to the most probable results is an approximate solution of the equations resulting from the method of least squares.

The direction of the meridian has been determined by observations of the elongations of α, ζ, λ Urs. min. and 51 Cephei; at six of the stations at which these observations have been made, the probable error of the result is under $0''\cdot40$, at twelve under $0''\cdot50$, at thirty-four under $0''\cdot70$, and at fifty-one under $1''\cdot00$.

Measured Base Lines.

The account of the measurement with Ramsden's steel chain of the base lines on Hounslow Heath in 1791, on Salisbury Plain in 1794, on Misterton Carr in 1801, and on Rhuddlan Marsh in 1806, will be found in the 'Account of the Trigonometrical Survey.' These base lines are all expressed in terms of Ramsden's brass scale at the temperature of 62° Fahrenheit. The chains were compared with Ramsden's prismatic bar (20 feet in length), which was laid off from the brass scale at the temperature of 54° Fahrenheit. By a series of comparisons of the Ordnance 10-foot standard iron bar (designated O_1) with Ramsden's 20 foot standard, made at Southampton, it was found that

$$\text{Ramsden's bar} = 20\cdot0007656 \text{ feet of } O_1,$$

so that any measurement expressed in terms of feet of Ramsden's bar at 62° must be multiplied by 1·0000383 to give feet of O_1, at the same temperature. Also to reduce a measurement expressed in terms of Ramsden's brass scale to the same in terms of Ramsden's bar, it must be increased by a quantity corresponding to the difference of the expansions of brass and iron for 8°; and taking these quantities as used in the reduction of the bases, it will be found that the multiplier is 1·0000328, and hence to reduce the old bases to feet of O_1, they must be multiplied by 1·0000711.

In 1816 a base line of five miles in length was measured by Major General Colby on Belhelvie Sands, Aberdeenshire: the measurement was effected with Ramsden's steel chains, and in precisely the same manner as the previous bases. The chains were compared with Ramsden's bar by Mr. Berge both before and after the measurement.

In 1826-27 the Lough Foyle Base was measured in the north of Ireland with Major General Colby's compensation bars. Of this measurement a description in detail has been published.†

In 1849 the old base line on Salisbury Plain was remeasured. This measurement exceeded the old measure, when reduced to the same standard, by a foot. The guns

* 'Astronomical Observations made with Ramsden's Zenith Sector,' 1842. 'Astronomical Observations made with Airy's Zenith Sector,' 1852.

† 'Account of the Measurement of the Lough Foyle Base,' by Captain Yolland, R.E., 1847.

marking the extremities of the old line were found imbedded very firmly in the earth, and in all probability in exactly their original positions.

By a series of comparisons instituted in 1834* between the Royal Astronomical Society's Scale and the Ordnance Standard O_2, it was determined that

Ordnance Standard $O_1 = 119{\cdot}997508$ mean inches of the centre yard of the Royal Astronomical Society's Scale;

also from Mr. Baily's comparison of this scale with the standard metre he determined†

Standard Metre $= 39{\cdot}369678$ mean inches of the centre yard of the Royal Astronomical Society's Scale.

From more recent observations, it appears that the Royal Astronomical Society's scale has undergone a permanent alteration of length; the interval however between the two series of observations above quoted was not sufficiently long to vitiate the connexion thus established between the Ordnance Standard and the metre. The resulting value of the metre in terms of O_1 is therefore

Standard Metre $= 3{\cdot}2808746$ mean feet of O_1

and hence since the metre $= 443{\cdot}296$ lines of the toise of Peru,

Toise $= 6{\cdot}3945438$ mean feet of O_1,

Reduction of the Triangulation.

If u represent the true ratio of the distance between any two points in a network of triangulation to the base line; A B C... A'... the true angles, whose observed values are $A+\alpha$, $B+\beta$, $C+\gamma \ldots A'+\alpha' \ldots$, then if u_1 be the calculated value of u obtained by using the series of observed angles ABC..., u'_1 the value obtained by using the series of observed angles A'B'C'....

$$u = f(ABC\ldots) = f(A'B'C'\ldots) = \ldots.$$

$$u_1 = u + a\alpha + b\beta + c\gamma + \ldots.$$

$$u'_1 = u + a'\alpha' + b'\beta' + c'\gamma' + \ldots.$$

and so on. Each different calculation of u will therefore give a different value for that quantity.

In the necessary existence of these discrepancies among the calculated values of u, it becomes of much importance to obtain the most probable value. In ordinary calculations this has been generally effected by assuming it to be the mean of all the calculated values $u_1\, u'_1\, u''_1 \ldots\ldots$ This might be improved upon by assigning to each value of u its proper weight by means of the weights of the observed angles, but the method would still be imperfect and discrepancies would still exist in other parts of the work.

From the above equations, though we cannot determine the precise value of u, yet we can obtain some precise information respecting the errors of observation; for we have evidently, since the quantities $abc\ldots a'b'c'\ldots$ are numerical, certain equations of condition between the unknown errors.

But the number of such equations of condition for the whole figure being necessarily less than the actual number of errors, an indefinite number of systems of corrections might be obtained that would satisfy all the geometrical relations of the triangulation. The question then is to determine that system which is the most probable, and the solution derived from the theory of probabilities is, that the most probable system of corrections $x\, x' \ldots$ is that which makes the function $\Sigma\,(wx^2)$ a minimum.‡

* The observations which were made by the late Lieutenant Murphy, R.E., are given in the 'Account of the measurement of the Lough Foyle Base.'

† Memoirs of the Royal Astronomical Society, vol. ix.

‡ Where w is the weight of the observation corresponding to the error x.

If n be the number of observed angles in a network of triangulation, and m the number of points, then $2(m-2)$ will be the number of angles absolutely required to fix all the points, consequently the geometrical figure must supply $n-2m+4$ equations of condition amongst the true angles or amongst the corrections to the observed angles: we have therefore $n-2+4$ equations of the form

$$0 = a_1 + b_1 x + c_1 x' + d_1 x'' + \dots$$
$$0 = a_2 + b_2 x + c_2 x' + d_2 x'' + \dots ,$$

which are to be determined so that the quantity

$$U = wx^2 + w'x'^2 + w''x''^2 + \dots$$

shall be a minimum. Multiplying the equations of condition by unknown quantities $\lambda_1 \lambda_2 \lambda_3 \dots$, we obtain by the theory of maxima and minima of functions of many variables,

$$wx = b_1\lambda_1 + b_2\lambda_2 + b_3\lambda_3 + \dots$$
$$w'x' = c_1\lambda_1 + c_2\lambda_2 + c_3\lambda_3 + \dots$$
$$w''x'' = d_1\lambda_1 + d_2\lambda_2 + d_3\lambda_3 + \dots$$

Substituting the values of $xx' \dots$ in terms of $\lambda_1\lambda_2 \dots$ as obtained from these equations, in the equations of condition we get a system of equations from which $\lambda_1\lambda_2 \dots$ may be determined; and having obtained the numerical values of these quantities, the last set of equations will give the numerical values of the required corrections $xx' \dots$

In order that the results of the triangulation, as applied to the determination of the figure of the earth, might have the greatest weight possible, the most probable system of corrections has been calculated according to Bessel's method, shortly described above. The principal and only objection to the application of this method of obtaining the most trustworthy results, is the extremely voluminous and tedious nature of the calculations. The total number of equations of condition for the triangulation is 920; if therefore the whole were to be reduced in one mass, it would involve, as a small part of the work, the solution of an equation of 920 unknown quantities. The following method of approximation therefore was adopted: the triangulation was divided into twenty-one parts or figures, each affording a not unmanageable number of equations of condition; four of these parts, not adjacent, were first adjusted by the method just explained. The corrections determined in these figures were substituted, so far as they entered, in the equations of condition of the adjacent figure, and the sum of the squares of the remaining corrections in that figure made a minimum. Thus each division of the triangulation, with the exception of the four specified above, is dependent upon one or more of the figures to which it is adjacent.

The average number of equations in each figure is about 44; the greatest number of equations in any one figure is 77. Each figure was worked by two independent computers. This of itself alone would have been insufficient to secure freedom from error, but the final working of every possible triangle, after the corrections were applied to the observed angles, secured perfect accuracy.

Corrections to all the observed bearings having been obtained in the manner explained, it is clear that since all the geometrical relations of the figure are satisfied, no discrepancies can present themselves between the calculated values of the distance between any two points by whatever series of angles it may be obtained. The triangles are calculated by Legendre's theorem. This theorem may be applied to triangles of any magnitude, up to two or three hundred miles, without fear of error. The greatest errors that can result in the values of the sides a, b of a spheroidal triangle, as calculated from the side c by spherical trigonometry, using the geometric mean of the principal radii of curvature of the surface for the mean latitude of the triangle as the radius of the sphere, are (the position of the triangle in *azimuth* being the variable quantity with respect to which the errors are the greatest possible),

$$\epsilon_a = \mu (4l^2 + m^2 + 4n^2)^{\frac{1}{2}}$$

$$\epsilon_b = \mu (l^2 + 4m^2 + 4n^2)^{\frac{1}{2}}$$

$$\mu = \frac{e^2 \cos^2 \lambda . abc}{12R^2 \sqrt{1-n^2}}$$

where R is the radius of the sphere, e the eccentricity of the earth's surface, lmn the cosines of the angles of the triangle opposite abc respectively, and λ its mean latitude.

Comparison of Bases.

The absolute length of any side, or the linear scale of the triangulation, is made to depend on the bases measured with the compensation bars at Lough Foyle and on Salisbury Plain. The discrepancy between the measured and calculated lengths of these bases is about 5 inches; this discrepancy is divided so that each of the two bases shall exhibit an error proportional to the square root of its length: the comparison of all the bases is then as follows :—

Date.	Bases.	Length in terms of Ramsden's Scale.	Length in terms of Ordnance Standard.	Length in Triangulation.	Difference.
		ft.	ft.	ft.	ft.
1791.	Hounslow Heath.	27404·24	27406·190	27406·363	+0·173
1794.	Salisbury Plain .	36574·23	36576·830	36577·656	+0·826
1801.	Misterton Carr. .	26342·19	26344·060	26343·869	−0·191
1806.	Rhuddlan Marsh.	24514·26	24516·000	24517·596	+1·596
1817.	Belhelvie.	26515·65	26517·530	26517·770	+0·240
1827.	Lough Foyle. . .	....	41640·887	41641·103	+0·216
1849.	Salisbury Plain .	....	36577·858	36577·656	−0·202

Latitudes and Longitudes.

For short distances the ordinary formulæ are sufficient, but in the case of distances above 80 or 100 miles the following formulæ are used, A being the given point, and B that whose latitude and longitude are required :—

Let s = distance AB measured on the surface of the earth.
ν = normal to minor axis at A
θ = angle subtended at the foot of this normal by the curve s
α = azimuth of B at A
α' = azimuth of A at B, both measured from the north
λ = latitude of A; $\kappa = 90 - \lambda$
λ' = latitude of B
ω = difference of longitude
ρ = radius of curvature of the meridian for the latitude $\frac{1}{2}(\lambda + \lambda')$

$$\tan \tfrac{1}{2}(a' + \zeta - \omega) = \frac{\sin \frac{1}{2}(\kappa - \theta)}{\sin \frac{1}{2}(\kappa + \theta)} \cot \tfrac{1}{2} a$$

$$\tan \tfrac{1}{2}(a' + \zeta + \omega) = \frac{\cos \frac{1}{2}(\kappa - \theta)}{\cos \frac{1}{2}(\kappa + \theta)} \cot \tfrac{1}{2} a$$

$$\lambda' - \lambda = \frac{s}{\rho} \frac{\sin \frac{1}{2} (a' + \zeta - a)}{\sin \frac{1}{2} (a' + \zeta + a)} \left(1 + \frac{\theta^2}{12} \cos^2 (a' - a) \right)$$

$$\theta = \frac{s}{\nu} + \frac{e^2 \theta^3}{6(1 - e^2)} \cos^2 \lambda \cos^2 a$$

$$\zeta = \frac{e^2 \theta^2}{4(1 - e^2)} \cos^2 \lambda \sin 2 a,$$

ζ being a minute angular correction here expressed, as also θ, in angular measure.

In the calculation of latitudes and longitudes we must suppose all points to be projected on a regular spheroidal surface (A), very nearly agreeing with the actual surface covered by the triangulation, then by equations of condition between the observed and calculated latitudes, longitudes, and azimuths, small alterations to the elements of the assumed spheroid and its position must be determined: this new spheroid (B) will be that most nearly representing the actual surface under consideration.

For the first spheroid, that determined by the Astronomer Royal as most nearly representing the earth's surface; namely,

$$a = 20923713 \text{ feet}$$
$$b = 20853810 \text{ feet}$$

was used as the spheroid of reference (A).

If we resolve the inclination of the actual surface at any point to that of the spheroid (B) at the same point, or rather its projection, into two inclinations, one north and the other east, and call these inclinations ξ_n and η_n, these quantities being positive when the actual surface, as compared with that of the regular surface, rises to the north and to the east, and if we put ξ and η for the same quantities at Greenwich, from which point the calculations of latitude and longitude and azimuths had their commencement, then each point at which the latitude has been observed will give an equation of the form

$$\xi^n = a + b\xi + c\eta + m\zeta a + n\zeta e,$$

and each point at which the longitude or direction of the meridian has been determined will give an equation of the form

$$\eta^n = a' + b'\xi + c'\eta + m'\zeta a + n'\zeta e,$$

in which ζa and ζe are the increments to the semi-axis major and eccentricity of the spheroid (A).

In consequence of the smallness of the coefficients $n\ n'$ in the latitude of Great Britain, the quantity ζe would have very little weight as determined from these equations.

Surface of Great Britain.

The approximate results derived from the above equations are, assuming $\zeta e = 0$.

$$\zeta a = 2536$$
$$\eta = 0$$
$$\xi = +1''\cdot 4,$$

so that the semi-axes of the spheroid most nearly representing the surface of Great Britain are

$$\left. \begin{aligned} a &= 20926249 \\ b &= 20856337 \end{aligned} \right\} \text{feet of Ordnance Standard } O_1.$$

$$\frac{a-b}{a} = \frac{1}{299\cdot 33}$$

Most Probable Deflections.

The last column of the following Table contains the most probable deflections at the various stations as resulting from a comparison of the actual observed latitudes with those of spheroid (B), or of the *apparent* and *mean* latitudes.

Stations.	Latitudes.				
	Observed.	Spheroid. (A).	Diff. Obs—Cal.	Spheroid (B).	Diff. Obs.--Cal.
	° ′ ″	″	″	″	″
Saint Agnes	49 53 33·94	30·78	−3·16	32·93	−1·01
Goonhilly	50 2 50·07	45·35	−4·72	47·42	−2·65
Hensbarrow	50 22 61·84	58·81	−3·03	60·73	−1·11
Port Valley	50 35 43·20	43·17	−0·03	44·95	+1·75
Week Down	50 35 51·42	50·28	−1·14	52·06	+0·64
Boniface Down	50 36 10·55	9·63	−0·92	11·41	+0·86
Dunnose	50 37 7·15	3·75	−3·40	5·53	−1·62
Black Down...........	50 41 8·89	10·29	+1·40	12·04	+3·15
Southampton............	50 54 46·97	47·23	+0·26	48·88	+1·91
Greenwich	51 28 38·30	38·30	0·00	39·70	+1·40
Hungry Hill...........	51 41 10·26	11·47	+1·21	12·94	+2·68
Feaghmaan	51 55 22·85	20·30	−2·55	21·68	−1·17
Precelly	51 56 45·18	44·76	−0·42	45·99	+0·81
Arbury Hill	52 13 27·01	27·29	+0·28	28·36	+1 35
Forth Mountain	52 18 57·91	56·83	−1·08	57·93	+0·02
Delamere	53 13 18·56	17·27	−1·29	17·93	−0·63
Clifton Beacon	53 27 30·27	27·02	−3·25	27·56	−2·71
South Berule	54 8 56·40	57·60	+1·20	57·87	+1·47
Tawnaghmore	54 17 41·34	39·61	−1·73	39·93	−1·41
Burleigh Moor	54 34 19·75	15·74	−4·01	15·80	−3·95
S. end of Lough Foyle Base.	55 2 38·74	33·93	−4·81	33·86	−4·88
Ben Lomond............	56 11 26·27	25·26	−1·01	24·64	−1·63
Kellie Law	56 14 51·43	53·69	+2·26	53·02	+1·59
Ben Heynish	56 27 16·88	19·64	+2·76	18·95	+2·07
Great Stirling	57 27 49·12	50·14	+1·02	48·94	−0·18
Cowhythe	57 40 68·92	60·49	−8·43	59·20	−9·72
Monach	58 21 20·84	23·54	+2·70	22·01	+1·17
Ben Hutig.............	58 33 6·47	5·12	−1·35	3·47	−3·00
North Rona	59 7 15·19	17·67	+2·48	15·80	+0·61
Balta	60 45 1·75	7·16	+5·41	4·51	+2·76
Gerth of Scaw	60 48 56·43	61·82	+5·39	59·15	+2·72
Saxavord	60 49 38·58	41·99	+3·41	39·31	+0·73

Arcs of Meridian.

The two longest meridional lines in the triangulation are from Dunnose, in the Isle of Wight, to Saxavord in the Shetland Isles, and from St. Agnes's Lighthouse, in the Scilly Islands, to North Rona; the lengths and amplitudes are as follows:—

	Length.	Astromical amplitude.
	feet.	° ′ ″
Dunnose to Saxavord	3729335·8	10 12 31·43
St. Agnes to North Rona	3370394·2	9 13 41·25

Arc of Parallel.

The volume of the Greenwich Observations for 1845 contains the account of the determination of the longitude of Feaghmaan, a station in the Island of Valentia on the West Coast of Ireland, by the transmission of chronometers.

The whole arc was subdivided by two intermediate stations, of which one was the Liverpool Observatory, the other a temporary observatory erected at Kingstown. The following Table contains the comparison of the astronomical and geodetical determinations :—

Stations	Observed Longitude W.	Geodetic Longitude.		Difference.	
		Spheroid (A).	Spheroid (B).	(A).	(B).
	m. s.	m. s.	m. s.	s.	s.
Liverpool......	12 0·05	12 0·35	12 0·26	+0·30	+0·21
Kingstown	24 31·20	24 31·48	24 31·26	+0·28	+0·06
Feaghmaan	41 23.23	41 23·02	41 22·74	−0·21	−0·49

Observatories.

The positions of the principal observatories, as calculated by their connexion with the Triangulation of the Ordnance Survey, are contained in the following Table :—

Names.	Latitudes.			Longitudes.		
	On Spheroid (B).	As observed.	Diff.	On Spheroid (B)	As observed	Diff.
	° ′ ″	° ′ ″	″	m. s.	m. s.	s.
Greenwich .	51 28 39·70	51 28 38 30	+1 40	0 0·00	0 0·00	0 00
Edinburgh .	55 57 17·57	55 57 23 20	−5·63	12 43·61	12 43 00	+0·61
Dublin ..	53 23 14·21	53 23 13 46	+0·75	25 20 87	25 22·00	−1·13
Cambridge .	52 12 51·90	52 12 51·63	+0·27	0 23 26	0 22·69	+0·57
Oxford ...	51 45 38 56	51 45 36·00	+2·56	5 2 91	5 2·60	+0·31
Durham ..	54 46 5 27	54 46 6·20	−0·93	6 20·25	6 19·75	+0·50
Liverpool .	53 24 47 06	53 24 47·80	−0·74	12 0 26	12 0·05	+0·21
Makerstown	55 49 1·83	55 49 6·00	−4·17	19 26·20	19 26·00	−1.80
Armagh ..	54 21 10·76	54 21 12·67	−1·91	26 35·52	26 35·50	+0.02

Figure of the Earth.

In obtaining the spheroid most nearly representing the measured arcs of meridian, we shall follow the method given by Bessel in his determination of the figure of the earth in Nos. 333 and 438 of the 'Astronomische Nachrichten ;' substituting for the English arc as used by him, the data of the present results, and for the Indian arc as used by him, the data contained at page 427 of Colonel Everest's 'Account of the Measurement of two sections of the Meridional Arc of India.'

Colonel Everest's measurements are expressed in terms of his standard 10-foot iron bar A, and the standard 6-inch scale A, twenty parts of any linear result being in terms of feet of the iron standard, and one part in terms of feet of the 6-inch scale. By means of the comparisons contained at page 436 of Colonel Everest's work, and at pages 101 and [40] of the 'Account of the Measurement of the Lough Foyle Base,' it will be found, that to reduce the results contained in the former work to feet of O_1, they must be multiplied by ·99999026. There is, however, some uncertainty in the unit of measure of the earlier portion of the second East Indian Arc.

Peruvian Arc.—The data are a mean between the reduced results obtained by Delambre and Zach (Base du Syst. Metr. iii. 133, and Mon. Corresp. xxvi. 52).

Indian Arc.—The data for the first Indian Arc are given in Vol. viii. of the Asiatic Researches, page 137.

French Arc.—The data for this arc will be found in the Base du Syst. Metr. ii. 565, 615. and iii. 548, 549.

Hanoverian Arc. —From Gauss' Breitenunterschied, &c , p. 71.

Danish and Russian Arcs, as used by Bessel, Astronomische Nachrichten, No. 333.

Prussian Arc.— Gradmessung in Ostpreussen : Bessel, 1838.

Swedish Arc.—Exposition des Opérations Faites en Lapponie : Svanberg.

1. Peruvian Arc.

	Latitude.	Amplitude.	Distance between the parallels.
	° ′ ″	° ′ ″	toises.
Tarqui	−3 4 32·068		
Cotchesqui	+0 2 31·387	3 7 3·455	176875·5

2. First East Indian Arc.

	Latitude.	Amplitude.	Distance between the parallels.
			feet.
Trivandeporum	11 44 52·590		
Pandree	13 19 49·018	1 34 56·428	574327·9

3. Second East Indian Arc.

	Latitude.	Amplitude.	Distance between the parallels.
			feet.
Punnæ..............	8 9 31·722		
Damargida	18 3 15·292	9 53 43·570	3591744·06
Kalianpur	24 7 11·262	15 57 39·540	5794648·82
Kaliana	29 30 48·322	21 21 16·600	7755786·84

4. French Arc.

	Latitude.	Amplitude.	Distance between the parallels.
			toises.
Formentera	38 39 56·11		
Mountjouy	41 21 44·96	2 41 48·85	153673·61
Barcelona	41 22 47·90	2 42 51·79	154616·74
Carcassonne	43 12 54·30	4 32 58·19	259172·61
Evaux	46 10 42·54	7 30 46·43	428019·31
Panthéon............	48 50 49·37	10 10 53·26	580312·41
Dunkirk	51 2 8·85	12 22 12·74	705257·21

5. English Arc.

	Latitude.			Amplitude.			Distance between the parallels.
							feet.
Dunnose	50	37	7·15				
Southampton	50	54	46 97	0	17	39·82	107807·19
Greenwich	51	28	38 30	0	51	31·15	313716·97
Arbury Hill	52	13	27·01	1	36	19·86	586356·34
Clifton	53	27	30·27	2	50	23·12	1036581·55
Kellie Law	56	14	51·43	5	37	44·28	2055737·20
Great Stirling	57	27	49·12	6	50	41·97	2499839·45
Saxavord	60	49	38 58	10	12	31·43	3729335·78

6. Hanoverian Arc.

							toises.
Göttingen	51	31	47·85				
Altona	53	32	45·27	2	0	57·42	115163·725

7. Danish Arc.

Lauenburg	53	22	17·046				
Lyssabbel	54	54	10·352	1	31	53·306	87436·538

8. Prussian Arc.

							toises.
Trunz	54	13	11·466				
Königsberg	54	42	50·500	0	29	39·034	28211·629
Memel	55	43	40·446	1	30	28·980	86176·975

9. Russian Arc.

							toises.
Bélin	52	2	40·864				
Nemesch	54	39	4·519	2	36	23·655	148811·418
Jacobstadt	56	30	4·562	4	27	23·698	254543·454
Bristen	56	34	51·550	4	32	10·686	259110·085
Dorpat	58	22	47·280	6	20	6·416	361824.461
Hochland	60	5	9·771	8	2	28·907	459363·008

10. Swedish Arc.

							toises.
Malörn	65	30	30·265				
Pahtawara	67	8	49·830	1	37	19·565	92777·981

If ρ be the radius of curvature of the meridian at a point whose latitude is λ,

$$\rho=\frac{a(1-e^2)}{(1-e^2\sin^2\lambda)^{\frac{3}{2}}};$$

or if we make

$$\frac{a-b}{a+b}=n,\ e^2=\frac{4n}{(1+n)^2},$$

$$\therefore\ \rho=\frac{a(1-n)(1-n^2)}{(1+2n\cos 2\lambda+n^2)^{\frac{3}{2}}},$$

which being expanded becomes

$$\rho=a(1-n)(1-n^2)\mathrm{N}\{1-2\alpha\cos 2\lambda+2\alpha'\cos 4\lambda-\ldots\}$$

$$\mathrm{N}=1+\left(\frac{3}{2}\right)^2 n^2+\left(\frac{3.5}{2.2}\right)^2 n^4+\ldots$$

$$\mathrm{N}\alpha=\frac{3}{2}n+\frac{3.5}{2.4}\cdot\frac{3}{2}n^3+\ldots\ldots$$

$$\mathrm{N}\alpha'=\frac{3.5}{2.4}n^2+\frac{3.5.7}{2.4.6}\cdot\frac{3}{2}n^4+\ldots\ldots$$

If s be the meridian distance between the points whose latitudes are $\lambda_1\lambda_2$

$$s=\int_{\lambda_1}^{\lambda_2}\rho.d\lambda;$$

and putting $\lambda_2-\lambda_1=\phi$, $2\lambda=\lambda_1+\lambda_2$,

$$s=\frac{180g}{\pi}\left\{\phi-2\alpha\sin\phi\cos 2\lambda+\alpha'\sin 2\phi\cos 4\lambda-\ldots\right\},$$

where g is the length of a mean degree of the meridian determined by the relation

$$g=\frac{\pi}{180}a(1-n)(1-n)^2)\mathrm{N}.$$

Hence if s be the meridian distance of two points whose latitudes are λ_1+x_1 and λ_2+x_2, we must substitute in this equation $\phi+x_2-x_1$ for ϕ, neglecting the influence of the small quantities x on the mean latitude of the arc; after this substitution we obtain

$$x_2-x_1=\mu\left(\frac{s\pi}{180g}-\phi+2\alpha\sin\phi\cos 2\lambda-\alpha'\sin 2\phi\cos 4\lambda\right)$$

$$\mu=1+2\alpha\cos\phi\cos 2\lambda.$$

Now let $g_1\ \alpha_1$ be approximate values of g and α, so that

$$\frac{1}{g}=\frac{1+i}{g_1},\quad \alpha=\alpha_1(1+k).$$

Then substituting in the preceding equation, we have finally

$$x_2 - x_1 = \mu\left\{\frac{3600}{g_1}s - \phi + P_1 \frac{1}{6}P_2\right\}$$
$$+\mu\left\{\frac{3600}{g_1}s\right\}i + \mu\left\{P_1 - \frac{1}{3}P_2\right\}k,$$

where x_1 x_2 and ϕ are expressed in seconds, and

$$P_1 = \frac{2\alpha_1}{\sin 1''}\sin\phi\cos 2\lambda$$

$$P_2 = \frac{5\alpha_1^2}{\sin 1''}\sin 2\phi\cos 4\lambda.$$

This equation contains the relation between the corrections to the terminal latitudes of a measured line s required to bring them into accordance with the measured distance, the elements of the spheroid of reference being as expressed above in g_1 a_1 i k. An arc in which there are n observed latitudes will therefore afford $n-1$ equations of the form

$$x_2 - x_1 = m + ai + bk\,;$$

the quantities ik must then be determined so as to make the function

$$x_1^2 + x_2^2 + x_3^2 + \ldots.$$

a minimum.

The final equations thus deduced are

$$0 = M + Ai + Bk$$
$$0 = M' + Bi + B'k$$

$$M = \Sigma\left\{(am) - \frac{(a)(m)}{r}\right\} \qquad M' = \Sigma\left\{(bm) - \frac{(b)(m)}{r}\right\}$$

$$A = \Sigma\left\{(a)^2 - \frac{(a)^2}{r}\right\} \qquad B = \Sigma\left\{(ab) - \frac{(a)\,(b)}{r}\right\} \qquad B' = \Sigma\left\{(b^2) - \frac{(b)^2}{r}\right\},$$

where r is the number of observed latitudes in any arc, the symbol Σ signifying summation with respect to the different arcs.

Bessel adopts the approximate elements $g_1 = 57008$ toises, $a^1 = \frac{1}{400}$; the equations for the different arcs are then as follows, putting $10000\,i = p$ and $10\,k = q$.

1. Peruvian Arc.

$$x_1^{(1)} - x_1 = +1{\cdot}966 + 1{\cdot}1225\,p + 5{\cdot}6959\,q.$$

2. First Indian Arc.

$$x_2^{(1)} - x_2 = +0{\cdot}937 + 0{\cdot}5697\,p + 2{\cdot}5835\,q.$$

3. Second East Indian Arc.

$$x_3^{(1)} - x_3 = +\ 5{\cdot}346 + 3{\cdot}5628\,p + 15{\cdot}9269\,q.$$

$$x_3^{(2)} - x_3 = +\ 4{\cdot}801 + 5{\cdot}7458\,p + 24{\cdot}0257\,q.$$

$$x_3^{(3)} - x_3 = +12{\cdot}440 + 7{\cdot}6875\,p + 29{\cdot}7981\,q.$$

4. French Arc.

$$x_4^{(1)}-x_4=+3\cdot991+0\cdot9713\,p+0\cdot8601\,q.$$

$$x_4^{(2)}-x_4=+0\cdot646+0\cdot9772\,p+0\cdot8642\,q.$$

$$x_4^{(3)}-x_4=+0\cdot026+1\cdot6378\,p+1\cdot1889\,q.$$

$$x_4^{(4)}-x_4=+5\cdot035+2\cdot7041\,p+1\cdot2671\,q.$$

$$x_4^{(5)}-x_4=+1\cdot191+3\cdot6655\,p+0\cdot8659\,q.$$

$$x_4^{(6)}-x_4=+5\cdot171+4\cdot4537\,p+0\cdot2051\,q.$$

5. English Arc.

$$x_5^{(1)}-x_5=+\ 3\cdot772+0\cdot1064\,p-0\cdot1038\,q.$$

$$x_5^{(2)}-x_5=+\ 3\cdot735+0\cdot3095\,p-0\cdot3176\,q.$$

$$x_5^{(3)}-x_5=+\ 4\cdot302+0\cdot5784\,p-0\cdot6308\,q.$$

$$x_5^{(4)}-x_5=+\ 1\cdot258+1\cdot0224\,p-1\cdot2226\,q.$$

$$x_5^{(5)}-x_5=+\ 7\cdot874+2\cdot0272\,p-2\cdot8959\,q.$$

$$x_5^{(6)}-x_5=+\ 7\cdot127+2\cdot4649\,p-3\cdot7683\,q.$$

$$x_5^{(7)}-x_5=+10\cdot883+3\cdot6763\,p-6\cdot6163\,q.$$

6. Hanoverian Arc.

$$x_6^{(1)}-x_6=+5\cdot679+0\cdot7263\,p-0\cdot9224\,q.$$

7. Danish Arc.

$$x_7^{(1)}-x_7=-0\cdot369+0\cdot5513\,p-0\cdot8537\,q.$$

8. Prussian Arc.

$$x_8^{(1)}-x_8=-0\cdot368+0\cdot1779\,p-0\cdot2852\,q.$$

$$x_8^{(2)}-x_8=+3\cdot790+0\cdot5433\,p-0\cdot9157\,q.$$

9. Russian Arc.

$$x_9^{(1)}-x_9=+0\cdot248+0\cdot9384\,p-1\cdot3293\,q.$$

$$x_9^{(2)}-x_9=+5\cdot110+1\cdot6049\,p-2\cdot5184\,q.$$

$$x_9^{(3)}-x_9=+5\cdot939+1\cdot6337\,p-2\cdot5741\,q.$$

$$x_9^{(4)}-x_9=+2\cdot909+2\cdot2809\,p-3\cdot9289\,q.$$

$$x_9^{(5)}-x_9=+5\cdot276+2\cdot8953\,p-5\cdot3824\,q.$$

10. Swedish Arc.

$$x_{10}^{(1)}-x_9=+0\cdot507+0\cdot5839\,p-1\cdot9711\,q.$$

From which we obtain the quantities for the different arcs:—

No. of Arc.	(m)	(a)	(b)	(am)	(aa)	(ab)	(bm)	(bb)
1.	+ 1·996	+1·1225	+ 5·6059	+ 2·2068	1·2600	+ 6·2926	+ 11·0211	31·4261
2.	+ 0·937	0·5697	+ 2·5835	+ 0·5338	0·3246	+ 1·4718	+ 2·4207	6·6745
3.	+22·587	16·9961	+69·7507	+142·2645	104·8052	+423·8645	+581·1810	1718·8272
4.	+ 5·990	14·4096	+ 5·2513	+ 18·3309	45·1641	+ 11·1409	− 0·2661	5·2976
5.	+38·951	10·1851	−15·5553	+ 78·8502	25·1874	− 41·2067	−127·4937	68·3661
6.	+ 5·679	0·7263	− 0·9224	+ 4·1247	0·5275	− 0·6750	− 5·2780	0·8638
7.	− 0·369	0·5513	− 0·8537	− 0·2034	0·3039	− 0·4706	+ 0·3150	0·7288
8.	+ 3·422	0·7212	− 1·2009	+ 1·9936	0·3268	− 0·5482	− 3·3655	0·9198
9.	+19·482	9·3532	−15·7331	+ 40·0469	19·7106	− 34·0396	− 68·3130	59·1418
10.	− 0·507	+0·5839	− 1·9711	− 9·2960	0·3409	− 1·1509	+ 0·9994	3·8852

No. of Arc.	M.	A.	B.	M′	B′
1.	+ 1·1034	0·6300	+ 3·1463	+ 5·5106	15·7131
2.	+ 0·2669	0·1623	+ 0·7359	+ 1·2104	3·3373
3.	+46·2918	32·5885	+127·4920	+177·3163	502·5376
4.	+ 6·0003	15·5021	+ 0·3313	− 4·7597	1·3583
5.	+29·2602	12·1204	− 21·4027	− 51·7569	38·1202
6.	+ 2·0624	0·2638	− 0·3375	− 2·6390	0·4319
7.	− 0·1017	0·1519	− 0·2353	+ 0·1575	0·3644
8.	+ 1·1710	0·1534	− 0·2595	− 1·9957	0·4391
9.	+ 9·6768	5·1302	− 9·5138	− 17·2270	17·8868
10.	− 0·1480	0·1705	− 0·5755	+ 0·4997	1·9426
Sums	+95·5831	66·9731	+ 99·3812	+106·3162	582·1313

The final equations are therefore—

$$0=+\ 95\cdot5831+66\cdot9731\,p+\ 99\cdot3812\,q$$

$$0=+106\cdot3162+99\cdot3812\,p+582\cdot1313\,q,$$

from which

$$p=-1\cdot548450$$

$$q=+0\cdot081718$$

These quantities, when substituted in the equations of condition, give the following values of the corrections required :—

1. Peruvian Arc.

	″
Tarqui	−0·360
Cotchesqui	+0·360

2. First Indian Arc.

Trivandeporum	−0·134
Pandree	+0·134

3. Second Indian Arc.

Punnæ	−0·492
Damargida	+0·638
Kalianpur	−2·625
Kaliana	+2·479

4. French Arc.

Formentera	+2·270
Mountjouy	+4·828
Barcelona	+1·474
Carcassonne	−0·142
Evaux	−6·848
Panthéon	−2·144
Dunkirk	+0·562

5. English Arc.

Dunnose	−2·738
Southampton	+0·860
Greenwich	+0 491
Arbury Hill	+0·616
Clifton	−3·164
Kellie Law	+1·760
Great Stirling	+0 264
Saxavord	+1·911

6. Hanoverian Arc.

	″
Göttingen	−2·239
Altona	+2·239

7. Danish Arc.

Lauenburg	+0·646
Lyssabbel	−0·646

8. Prussian Arc.

Trunz	−0·736
Königsberg	−1·402
Memel	−2·138

9. Russian Arc.

Bélin	−0·619
Nemesch	−1·932
Jacobstadt	+1·800
Bristen	+2·579
Dorpat	−1·563
Hochland	−0·260

10. Swedish Arc.

Malörn	+0·786
Pahtawara	−0·786

The values of the axes are—

$$a=\frac{180g}{\pi N(1-n^2)^2}(1+n)$$

$$b=\frac{180g}{\pi N(1-n^2)^2}(1-n),$$

which in terms of g_1 p and q, are—

$$a=\frac{601}{600}\cdot\frac{180g_1}{\pi}\left(1-\frac{n^2}{4}\right)-\frac{180g_1}{10000\pi}\left(p-\frac{10}{6}q\right)+\ldots$$

$$b=\frac{599}{600}\cdot\frac{180g_1}{\pi}\left(1-\frac{n^2}{4}\right)-\frac{180g_1}{10000\pi}\left(p+\frac{10}{6}q\right)+\ldots.$$

If we put ϵ for the mean error of an equation,

$$\text{Mean error of } p\pm\lambda q=\frac{\epsilon}{291\cdot07}\sqrt{1267\cdot2\mp258\cdot7\lambda=115\cdot3\lambda^2}$$

Now the sum of the squares of the errors, or quantities x, is 160·26;

$$\therefore\ \epsilon=\sqrt{\frac{160\cdot26}{38-12}}=\pm2\cdot48.$$

The values of a and b, and their mean errors, are consequently

$a=20924933$; mean error $\pm$ 800

$b=20854731$; mean error $\pm$ 606.

The ratio of the axes is expressed by the relation

$$a:b::\frac{1}{2n}+\frac{1}{2}:\frac{1}{2n}-\frac{1}{2}$$

$$\frac{1}{2n}=300\ -30q+3q^2.$$

Consequently the compression is

$$\frac{a-b}{a}=\frac{1}{298\cdot07};\ \text{mean error of denominator } \pm2\cdot70.$$

The length of a degree of the meridian whose mean latitude is λ, is consequently

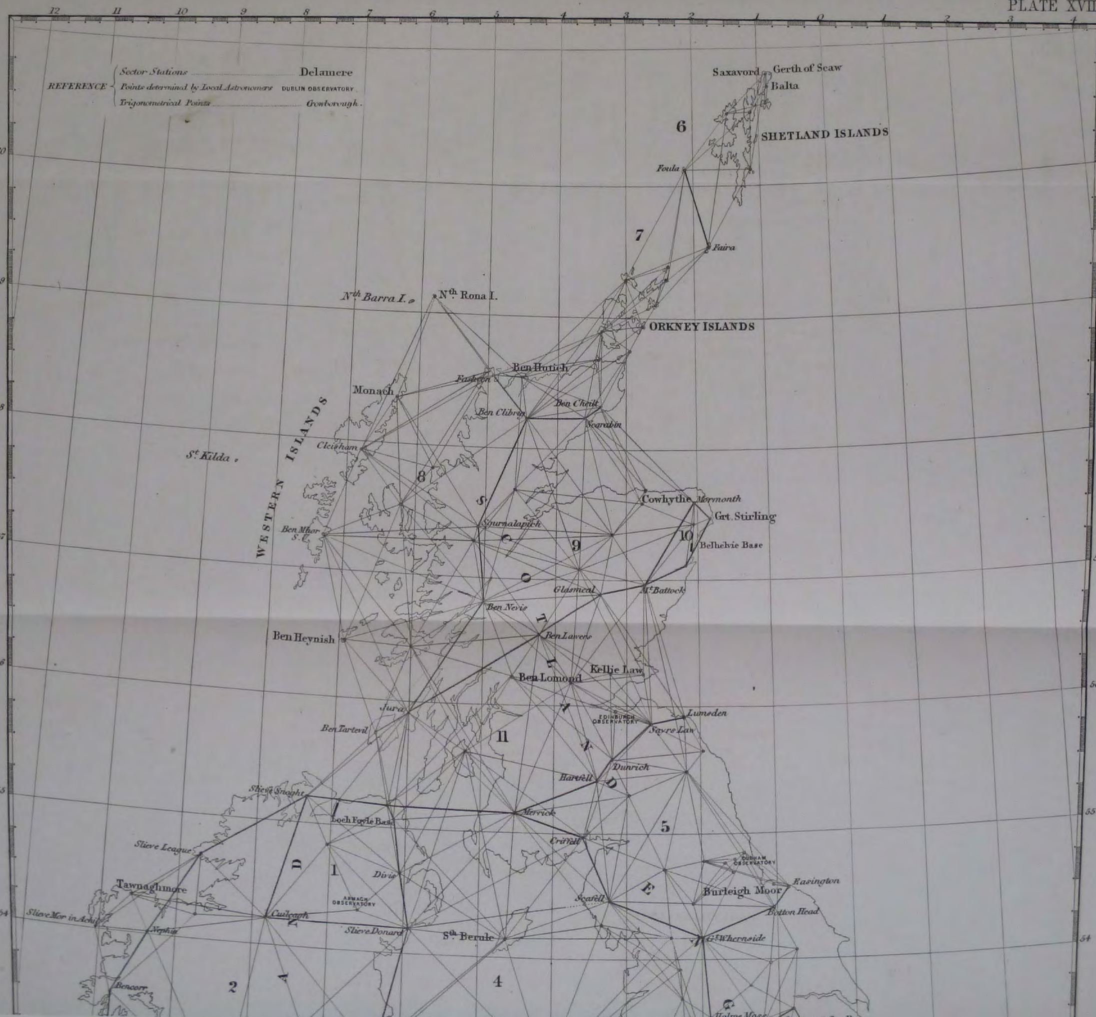
$$=364596\cdot61-1837.79\cos2\lambda+3\cdot85\cos4\lambda,$$

and the length of a degree of longitude in latitude λ

$$=365515\cdot56\cos\lambda-306\cdot96\cos3\lambda+0\cdot39\cos5\lambda.$$

Had the point Evaux in the French Arc, at which there is obviously some peculiar local disturbance, been omitted, we should have obtained $p=-1\cdot65000$, $q=+\cdot09341$: these values would have increased the values of the semi-axes as obtained above by about 200 feet each, and increased the compression to

$$\frac{a-b}{a}=\frac{1}{297\cdot72}.$$


REFERENCE
Sector Stations .... Delamere
Points determined by Local Astronomers DUBLIN OBSERVATORY
Trigonometrical Points .... Gowborough.
SHETLAND ISLANDS
Saxavord
Gerth of Scaw
Balta
Foula
Faira
ORKNEY ISLANDS
Nth Barra I.
Nth. Rona I.
Ben Hutich
Monach
Ben Clibrig
Ben Cheilt
Scarabin
St. Kilda
WESTERN ISLANDS
Cleisham
Cowhythe
Mormonth
Grt. Stirling
Belhelvie Base
Ben Mhor S.U.
Snurnalapich
Glasmeal
Mt. Battock
Ben Nevis
Ben Lawers
Ben Heynish
Ben Lomond
Kellie Law
Jura
Ben Tartevil
EDINBURGH OBSERVATORY
Lumsden
Sayrs Law
Dunrich
Hartfell
Slieve Snaght
Loch Foyle Base
Merrick
Criffell
Slieve League
Tawnaghmore
Divis
ARMAGH OBSERVATORY
DURHAM OBSERVATORY
Burleigh Moor
Easington
Scafell
Slieve Mor in Achil
Cuilcagh
Slieve Donard
Sth. Berule
Botton Head
Gt. Whernside
Nephin
Bencorr
SCOTLAND
IRELAND
ENGLAND

The corrections in the French Arc would then stand thus:—

Formentera. . . .	+1·319
Mountjouy. . . .	+3·788
Barcelona. . . .	+0·434
Carcassonne. . . .	—1·246
Panthéon. . . .	—3·457
Dunkirk. . . .	—0·839

and the correction for Evaux is increased to 8·059. The corrections for the other arcs are not materially altered, but are in general diminished: the mean error of the equations is ±2·05, which would diminish the probable error of the results in the proportion of 5 : 4.

SUMMARY.

We may state the results of this paper briefly as follows:—

1st. The four bases of verification, when their measured lengths are compared with their lengths as calculated from a mean of the Lough Foyle and Salisbury Plain bases, show the following discrepancies, expressed in feet:

Hounslow.	Misterton Carr.	Rhuddlan Marsh.	Belhelvie.
+0·173	−0·191	+1·596.	+0·240

2nd. The elements of the spheroid (B) most nearly representing the surface of Great Britain are—

	feet O_1.	miles.	
Equatorial semi-diameter	=20926249	=3963·305	compression $=\frac{1}{299·33}$.
Polar semi-diameter....	=20856337	=3950·064	

3rd. The elements of the spheroid (C) most nearly representing the whole of the measured arcs considered in this paper are—

	feet O_1.	miles.	
Equatorial semi-diameter	=20924933	=3963·057	compression $=\frac{1}{298·07}$.
Polar semi-diameter	=20854731	=3949·760	

4th. The lengths of the degrees of latitude and longitude in Great Britain are as in the following Table:

Mean Latitude.	From Ord. Survey, Spheroid (B).		From Spheroid (C).	
	Length in feet of 1° of latitude.	Length in feet of 1° of longitude.	Length in feet of 1° of latitude.	Length in feet of 1° of longitude.
50°	364936·33	235227·42	364912·12	235214·58
51	364999·14	230312·27	364975·19	230299·77
52	365061·50	225326·39	365037·81	225314·19
53	365123·34	220271·15	365099·92	220259·23
54	365184·58	215148·11	365161·41	215136·58
55	365245·15	209958·83	365222·23	209947·61
56	365304·96	204704·93	365282·29	204694·04
57	365363·96	199387·90	365341·53	199377·33
58	365422·06	194009·37	365399·88	193999·13
59	365479·20	188571·00	365457·26	188561·08
60	365535·30	183074·50	365513·59	183064·93

Plate xxxiv.

Is a diagram of the triangulation of the United Kingdom, and is one of the plates which have been engraved at the Ordnance Survey Office to illustrate the Account of the Trigonometrical Survey of the United Kingdom which is now in the press.

PAPER XV.

Syllabus of the Studies, Duties, &c., of an Officer of Royal Engineers, Arranged for the Assistance of the Junior Members of the Corps in Self-Education, and on the Assumption that they have fully availed themselves of all the Advantages and Opportunities afforded them at Woolwich and Chatham.

By COLONEL NELSON, Royal Engineers.

A Difficulty is something TO BE surmounted.

General.

Special study and cultivation of* —

A	Primarily	The Reasoning Power.
B	and	Imagination—more especially in reference to 'Design.'
C	Abstractedly	Invention.

And, as regards professional purposes :—

D	Powers of Expression (of Thought and Feeling)	Languages. Drawing.

E	Analysis	In reference to the all important habit of working from Whole to Part
F	Synthesis	—or Part to Whole—or with both processes in combination.

G Habits of Observation and Record.

H Scientific Pursuits—as in various ways useful and honourable—such as

Pure Mathematics, in reference to A, C, E, F, rather than to any direct application.

Mixed Mathematics—chiefly in reference to Astronomy, Geodesics, Mechanics, Pneumatics, Hydrostatics, and Hydraulics.

Astronomy.

Geology—mainly in relation to Building Material, and command of Supply of Water in the first instance.

Galvanism, Magnetism, Electricity—in reference to Telegraphic Communications, Electrotyping, Explosion of Charges, &c., &c.

* This is, of course, but a fragment of the whole scheme of Mental Culture.

Mineralogy and Chemistry; as subjects of general interest and utility.

The different branches of 'Natural History'—though not directly professional—supply varied and inexhaustible resource and occupation everywhere. Officers in the Colonies are, generally speaking, advantageously placed for amassing fresh information, which is sure of being thankfully received by the London Societies: such studies generally assist in the formation of E, F, and G.

I General—though by no means superficial—acquaintance with that WHOLE of which the work of the Engineer is but the *Part;—i. e.*, the Art of War: no officer ever attains to his full value in the Field—at Home—or in the Colonies—without due attention to this.†

J The general study of Strategics and Tactics.

K The study of Artillery, in its more immediate relation to Engineer duties, either in Garrison or in the Field.

L The study of Military Law, and such acquaintance with the laws and valuation of landed property as is necessary for managing that of the War Department.

M The study of Architecture, } in reference to present and future requirements.
N The study of Steam Power, }

IN THE FIELD.

1. Selection of Positions.
2. Conduct and Works of Attack and Defence.
3. Reconnoissances and Reports.
4. Communications { Bridges. Roads. Telegraphs.
5. Embarkation, Disembarkation: —Camp, Park, and Field Train duties; —Re-embarkation.
6. Regimental, Brigade, and Divisional duties in general.
7. Occasional and extemporaneous duty as Staff Officers.
8. Duty of Commanding Engineer and his Staff in the Field and Bureau.
9. The Commanding Engineer in the Council of War.

AT HOME OR IN THE COLONIES.

10. The Constructive Branch generally; in subordination to M.
11. Geodesic Operations.
12. Charge of War Department lands.
13. Regimental and Garrison duties.
14. Occasional and extemporaneous duties as Staff Officers.
15. Duty of the Commanding Engineer of the District.

† As an excellent introduction, see the prefatory paper in the 'Aide Mémoire,' by Lieutenant-Colonel Hamilton Smith, K.H., on the 'Art and Science of War;' then, the original article in the 'Encyclopædia Britannica,' of which this is a modification, suited to our insular and otherwise peculiar position. Before proceeding with any of the full catalogue of the most important works on War, given by Lieutenant-Colonel Smith at the end of his 'Aide Mémoire' paper, the attentive perusal of Dufour's 'Cours Elémentaire de Tactique' is recommended.

THE CONSTRUCTIVE BRANCH, considered in detail, with more especial reference to Nos. 2, 4, and 10 of the preceding.

(See Weale's Catalogue, for suitable Works.)

I. Familiar acquaintance with technical terms in the Triennial Schedules.

II. Processes, } in—
III. Daily Tasks, }

Excavation in different soils and rocks.
Pile-driving.
Diving-bell work.
Dredging.
Sod-work.
Lifting, Metalling, Gravelling, and Paving.
Boring for water.

Lime-burning.
Cement-burning.
Brick, drain-pipe, and tile-making.
Quarrying in different rocks.
Stone Mason's work.

Scaffolding and } in general.
Centering }
* Masonry.
* Brickwork.
Plastering.
Cementing.
Asphalting.

Sawyer's work.
*Carpentry.
*Joinery.
Cooper's work.
Turner's work.
Painting.
Glazing.
Paper-hanging.

*Ironwork in roofs, floors, &c.
Electrotyping.
Blacksmith's work.
Whitesmith's work.
Ironmongery.
Brazier's and Coppersmith's work.
Tinman's work.
Plumber's work.

NOTE.—More immediate attention should be paid to the five subjects marked*. See such authors as Nicholson, Tredgold, Barlow, Hodgkinson, and Fairbairn, as also many useful treatises in Weale's Series.

IV. Application of the preceding under all circumstances of Climate, Rock, Soil, &c., in Fortifications, viz.—

Systematic Works.	Foundations.
Irregular Works.	Escarps.
Advanced Works.	Counterscarps.
Towers of various sorts.	Countermines.
Detached Batteries.	Retaining walls.
Detached Posts.	Ramparts.
Inundations.	Embrasures.
&c. &c.	Loopholes.
	Platforms.
	Casemates and all vaulted works.
	Bridges.
	Magazines.
	Ordnance Stores.
	Artillery Stores.
	Side-arm Sheds, &c., &c.

In Barracks, Commissariat buildings, &c. } Complete in every item, as per Detailed Schedules; and keeping in view all Sanitary Subjects, *e. g.*,

Site and Aspect.
Air, as to general purity.
Water, ditto, and as to quantity.
Light.
Dryness.
And all constructive arrangements for Ventilation, Warming, Drainage, and Sewerage.

Boats.
Bridges.
Roads, Rail.
" Common.
Tunnels.
Canals.
Dams and Embankments.
Docks, Piers, and Wharves.
Light-houses.
Drainage, in general.
Waterworks, in general.

V. Office routine—from the Cheque-Book and Diary to the complete Finance of the District.

VI. Plant.

VII. Workshops; together with their respective assortments of Tools and Fitments.

VIII. Materials—their natures, powers, and application.

IX. Measurements of Artificer's work.

X. Drawing, generally.

XI. Surveying, including Military Topography, as the subordinate detail of Geodesics.

XII. Construction of Prices.

XIII. " Estimates.

XIV. " Specifications.

PAPER XVI.

On the Geometrical Projection of Two-thirds of the Sphere.

By COLONEL JAMES, R.E.,F.R.S.,M.R.I.,A., &c.,
Superintendent of the Ordnance Survey.

Sir John Herschel, in his 'Outlines of Astronomy,' says: "It is possible so to divide the globe into two hemispheres, that one shall contain *nearly all the land*, the other being almost entirely sea. It is a fact, not a little interesting to Englishmen, and, combined with our insular station in that great highway of nations, the Atlantic, not a little explanatory of our commercial eminence, that London (or more exactly Falmouth) occupies nearly the centre of the terrestrial hemisphere."

In verifying this interesting fact on a globe, it occurred to me to enquire what would be the central point of the projection which should embrace all the land in Europe, Asia, Africa, and America, and I found that this point would be in latitude 23° 30′ north, that is, on the northern tropic, and in longitude 15° east of Greenwich. This point is about 650 miles south of Tripoli, near a place called May Yan, in Africa.

But to make a projection of the sphere which should embrace so large a portion of the surface, I found that it would be necessary to make it as if we were looking into a hollow sphere, and seeing the continents as if they were on the internal surface. Then by taking the point of projection in the prolongation of the axis of the great circle whose pole was in the *central position*, and at the distance of half the radius from the surface of the sphere, I found that I could project on the plane of the circle drawn parallel to the above great circle, and at 23° 30′ from it towards the point of projection, exactly seven-tenths, or rather more than two-thirds of the surface of the sphere (see the Plate).*

This projection, which is strictly geometrical, has the great advantage of giving a good perspective representation of the surface, and it represents the different parts of the globe with little distortion, more especially in the central and circumpolar regions. I have used this same projection for representing the Pacific Ocean and the South Polar Regions by simply turning it upside down.

It is especially well suited for the representation of all such scientific facts as require to be exhibited on a large portion of the surface of the globe for properly comprehending them, such for example as the isothermal and isobarometrical lines, the lines of equal magnetic declination or the geological structure of different parts of the globe, the currents of the ocean, &c. It is more especially suited for maps of the stars, to which purpose, and for the representation of the lines of equal magnetic declination, I am now applying it.

HENRY JAMES,
Lieut.-Colonel Royal Engineers and Colonel.

Ordnance Survey Office,
Southampton, 1st May, 1858.

* This plate has been engraved from a reduction of the large engraving two feet in diameter, the impression of which, and of the projection shewing the Pacific Ocean and South Polar Regions, are sold by the agents for the sale of the Ordnance maps; the projection, with the meridians and parallels only engraved, are also sold by the agents, or may be had from this office directly.—H. J.

GEOMETRICAL PROJECTION

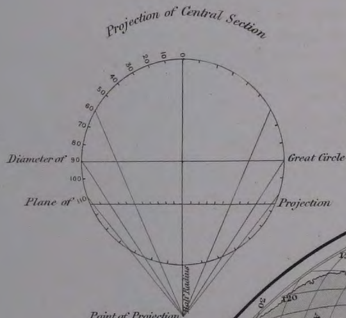
OF

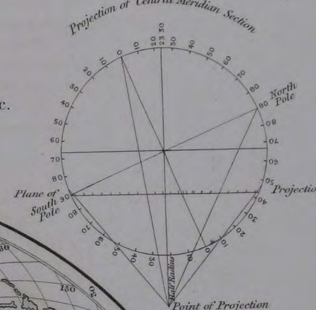
TWO THIRDS OF THE SPHERE

BY

Lieut[t] Colonel H. James, R.E. F.R.S. M.R.I.A. &c.

Superintendent of the Ordnance Survey.





ENGRAVED AT THE ORDNANCE MAP OFFICE SOUTHAMPTON

1857

FROM A REDUCTION MADE BY PHOTOGRAPHY

*Note*_ *The point of projection is in the axis of a great circle whose pole is in 15° E. Longitude and 23° 30′ North Latitude and at the distance of half the radius above the surface of the sphere. The plane of projection is parallel to this great circle at the distance of 23° 30′ from it towards the point of projection. The projection therefore embraces 227° of a great circle, and consequently $\frac{7}{10}$ or rather more than $\frac{2}{3}$ of the surface of the sphere. The hemisphere was first projected by Hipparchus 200 years before Christ, but this is the first time that a Geometrical projection of more than a hemisphere has been made.*

PAPER XVII.

Account of an Extraordinary Instance of Rapid Decay of Girders in the Storehouses at St. John's, Newfoundland.

By CAPTAIN BINNEY, Royal Engineers.

As this failure presents some peculiar features, it may perhaps be useful to give a short description of the position of the buildings in which it was observed.

Signal Hill is the highest point on the north side of the Narrows or entrance to St. John's harbour, its summit, which lies nearly N.E. and S.W., being 510 feet above the sea, and very frequently enveloped in dense fog. From its commanding position it has always been considered the best site for the construction of a citadel, and consequently, in the year 1836, a range of stone barracks was commenced on the edge of the rock looking towards the ocean, the basement wall on the sea face being exposed to the air. This range was completed in 1839, but in 1842 the barracks were vacated, and in the same year, by a 'Board's order,' they were appropriated as Ordnance storehouses.

On the 19th September, 1846, St. John's was visited by a violent storm or hurricane, which, in addition to much other damage, entirely unroofed the two houses, A and B, and on subsequent examination, the walls were found to be so much shaken that the Commanding Royal Engineer did not think it safe to place the weight of a new roof upon them, and accordingly he obtained permission from the Inspector General of Fortifications to pull them down. When the workmen commenced taking up the boards of the ground-floor, it was found that nearly all the joists and girders were completely decayed, the joists in many cases falling of themselves as soon as the boards were removed; and in one particular instance a girder was so entirely decomposed that on raising the joists it fell and crumbled into small fragments not more than 8 or 10 inches long by 2 inches square; the scantling of this girder was $14'' \times 12''$.

These circumstances led the writer to examine the ground-floors of houses C and D, when it was found that in these houses also the joists and girders were all more or less decayed, but not so much as those in A and B, though at first it was supposed that they would have been worse, on account of vegetables having been kept in the basement by the Troops. There was however a much greater appearance of white fungus in these than in A and B, probably occasioned by the vegetables.

The officers' wine cellar was the only part of the basement over which the joists were sound. This cellar was in the centre of the basement, and it had a kitchen in rear, and an excavated space in front covered by the floor above; from both these it was separated by stone walls, on which the ends of the joists, which were in three lengths, rested. It was also ceiled with lath and plaster, and consequently the joists were entirely closed in from the external air, whilst those in front and rear, having one end resting on the outer walls, were completely decayed.

From these appearances, it seems that it might be worth the consideration of those who have to deal with these matters to decide whether, in such positions as Signal Hill, where there is a constant damp arising both from the sea and the rock, the reverse of the received theory of ventilation would not be found correct, and whether in those cases it would not be advisable to exclude the external air as much as possible, and also to build the walls, at least in the basement, double, leaving a small space between, with the ends of the joists or girders resting on the inner wall, and to turn a $4\frac{1}{2}$ or 9 inch brick arch under the joists of the ground floor, the scantling of which might in that case be diminished.

It is submited that this last precaution would be attended with great benefit in all barracks, in climates where the Troops are obliged to keep vegetables in frost-proof cellars.

PAPER XVIII.

Notes on the Demolition of Fort Nicholas at Sebastopol, by the French, in 1855, Obtained from an Officer of the Corps du Génie.

By LIEUT. C. GORDON, Royal Engineers.

This work was constructed for the defence of the harbour of Sebastopol, and mounted 180 guns on the side facing the sea.

It consisted of casemates containing one gun in each stòry, and separated by piers 5 feet thick, the dimensions of the casemates being 39 feet long, 20 feet wide, and 12 feet high.

One half of the building consisted of three tiers of casemates, and was 50 feet high; the other half consisted of 2 tiers of casemates, with 2 cellars and a magazine underneath. The total length was 500 mètres, and attached to the rear of each extremity was a large magazine.

33 charges, of 2,860 lbs. each, were placed on the floor of the lower story in the alternate casemates, so as to be 16 yards apart, and 2 charges of 6,600 lbs. each were placed in the magazines at the extremities.

In the cellars, 2 charges of 1,540 lbs. were lodged, and one of 3,300 lbs. in the adjacent magazine.

	lbs.
Thus there were in the casemates. . . .	87,120
In the magazines at the ends.	13,200
In the cellars.	3,080
In the other magazine.	3,300
Total. . . .	106,700

PAPER XIX.

Account of a Pocket Reflecting Level, Manufactured by Messrs. Elliott.

By CAPTAIN H. SCOTT, R.E.

The annexed sketch represents a reflecting level, which promises to be very serviceable in the field, in ascertaining differences of level approximately, and in assisting the eye in sketching contour-lines. It is made by Messrs. Elliott and Co., 56, Strand, for 10s. 6d. (See Plate facing page 138.)

The brass tube B A has a draw tube B C, of which the eye end is perforated only with a small central hole.

The level D E has its brass casing open at the bottom as well as at the top; and corresponding with the bottom opening there is also an opening in the upper part of the tube, so that an inclined semi-elliptical mirror, placed at F, may reflect the image of the level bubble to the eye at B, when the tube is held so that the line joining the eye-hole and the lower edge of the mirror is in a horizontal position.

In a trial made with the instrument between points half-a-mile and a mile apart, and differing in altitude 130 and 220 feet respectively, the result obtained was in each case within 18 inches of the truth.

NOTE.—This instrument can be carried in the waistcoat pocket; it has been much used by Mr. Gisborne, and other Civil Engineers, in taking trial sections for railways, and has been found very convenient in the field.—ED.

PAPER XX.

On Curing Smoky Kitchen-Chimneys by the Application of Colonel Sandham's Method.

By MAJOR HASSARD, Royal Engineers.

Having, some years since, read in Vol. II of the 1st Series of Professional Papers, Sir Charles Pasley's remarks on "Colonel Sandham's and other methods of curing smoky chimneys," I endeavoured to apply the same to kitchen and barrack ranges, where from the cook requiring space on the hobs, the ordinary method could not be applied.

In all cases I have been very successful, and knowing from experience that smoky chimneys are the constant troubles of a District Engineer, I think that an account of this very simple method may assist a brother officer in distress when some obstinate kitchen has defied the attemps of all before him.

The method is as follows:—I build up two half brick piers, marked *a*, *a* in the Plate, either on edge or flat, one flush with the cheek of the oven, and the other flush with the moveable cheek of the grate at the greatest distance at which it is when in ordinary use by the family; and, of course, if they are in the habit of using the fire-place when widened to its full extent, the pier should be placed flush with the outer cheek, as shewn by dotted lines in the elevation, Fig. 2.

These piers are carried up to the height of the chimney-arch or a little beyond it. The whole of the mouth of the flue is then covered in horizontally with slates, with the exception of the portion between the two piers, and a slate, *b*, or a piece of iron, which is better, is nailed on in front of the piers, closing it as far as to within 6 or 8 inches of the top of the range. All the joints should be perfectly air-tight, which is easily effected by laying a little mortar over them on the upper side.

I have never known this method to fail entirely, although it is not always quite perfect. In the lithographic press-room at Brompton Barracks, Chatham, the slight smoke, in one particular wind, on opening and shutting the door, is of such small importance that it is not considered necessary to re-set the grate, but this should be done. In three different places where I was stationed, the kitchen chimneys smoked, and each was cured by this arrangement; also the non-commissioned officers' mess-kitchen at Brompton Barracks, No. 6, hall of study, the kitchen of the new convict prison at Chatham, and the kitchen of the medical officers' quarters; and there is no doubt that even in the most obstinate case a most decided improvement takes place, and that until the flue requires sweeping it will not smoke.

I have generally regulated the depth of the flue by that of the back of the boiler or grate; but in any cases where there is no back on which to build, which will seldom occur, the bottom bricks must be corbelled out to support the columns.

Half a day's work of a bricklayer, a few bricks and slates, and a hod of mortar, are all that is required; but it would be a manifest improvement to make the flue of iron, with the front part made to slide up and down, so as to regulate the draught, as in some winds fire-places draw better than in others.

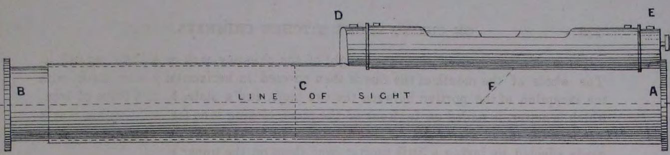
It is right that I should state the disadvantages of this method, which are—1st, that every time the flue is swept a bricklayer is required to put on the front slate; but nothing else need be removed; and 2nd, that it causes the fuel to burn away so fast that there is a large consumption; this is certainly the case, but it will be found that it will burn cinders and ashes, which are often thrown away because the fire will not consume them, so that in the end the actual consumption is not extravagant.

F. C. HASSARD, Major, Royal Engineers.

26th November, 1857.

REFLECTING LEVEL.

(Full Size.)



End View at A.

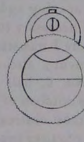


FIG. 1.

PLAN OF FIRE-PLACE.

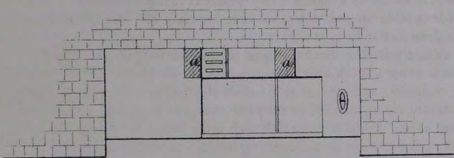
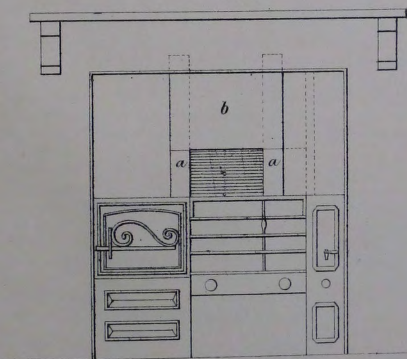
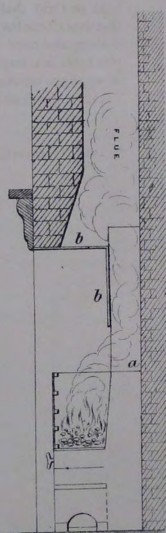


FIG. 3.

FIG. 2.





ELEVATION.

SECTION.

Scale ½ Inch = 1 Foot.

C. Moody Lith. 257, Holborn, London

PAPER XXI.

Remarks on the Application of Electricity to the Explosion of Mines,

By Dr. LOUIS FIGUIER,

Translated by CAPT. AKERS, Royal Engineers,

Accompanied by Notes on the Subject

by M. Du Moncel and Major Von Ebner,

Translated by Lieut.-Col. Bainbrigge, R.E.

The art of war having always profited by the discoveries of science, the applications of electricity could not fail to be made use of by armies in the field. The electric telegraph, for instance, has been most usefully employed in the war in the Crimea.

The conducting wire used for communication in the field is insulated by a covering of gutta-percha, and is generally laid on the surface of the ground, between the telegraphic stations. If the nature of the country will admit of it, it is more completely insulated by suspending it along a row of posts which may be speedily driven into the ground by a party of men told off for the purpose. Instruments of various construction are used for producing the necessary signals. The common needle instrument, which is generally preferred in England, may be used, or Morse's printing telegraph, or the dial telegraph, having on its circumference a certain number of symbols, the meaning of which has been previously agreed on.

M Hipp, of Berne, who enjoys a well deserved reputation in Switzerland, sent to the Exhibition in Paris, in 1856, a "Military Electric Telegraph," which is so well adapted to its particular object as apparently to possess every quality necessary for its efficiency. It is both simple and portable. Its size is such as to allow of the whole apparatus, including the Voltaic battery, which is of a new construction (saturated sand being used in place of the ordinary liquids) and all the materials necessary for an electric correspondence, being enclosed in a small box. The signalling apparatus is on Morse's principle, which has the advantage of recording the very words of the despatch, and thus serving as a reference for its authenticity. Several scientific commissions appointed in Switzerland, after carefully studying M. Hipp's arrangement, have acknowledged its advantages. It is therefore probable that this form of apparatus will entirely supersede the various instruments hitherto used by the armies of Europe.

But of all the uses of electricity for military purposes, none appears more manifestly advantageous than its application to the explosion of mines at considerable distances. For some years past the electric current has been thus applied, and this new application of its power has been attentively studied by the scientific Corps du Génie. Thanks to the researches of some distinguished officers, it has been made sufficiently practical to be adopted in our military works. Abroad, too, the same subject has been much studied, so that, although but a recent discovery, great advances have already been made in it. In Spain, for example, numerous experiments have been made on this subject, and with satisfactory results.

All the world has seen, in the various accounts of the last terrible episode of the siege of Sebastopol, that our enemies have not been behind hand in this new application of science to the attack and defence of places. It was by means of conducting wires that the Russians were able, after the taking of the Malakoff, to blow up, without danger to themselves, the numerous fortifications which they were compelled to abandon. It was owing to a providential circumstance that the great works of the Malakoff and the Redan escaped a similar destruction. While the British Troops were entering and occupying the works of the Redan, a sapper, hastily exploring the Russian batteries, came accidentally on a pretty thick cable, which he immediately cut through with his axe. On examination it was found that this cable consisted of a thick wire, covered with a thick coat of gutta-percha, and that it led to an enormous loaded chamber formed under the Redan, the mere discovery of which made the most hardy shudder at the thoughts of the frightful explosion they had so narrowly escaped. The wire was laid across the town, under the arm of the sea, and up the north bank, whence it was intended to fire the charge. This wire had scarcely been cut when the forts of Sebastopol blew up, one after another, filling our trenches with their fragments. The works of the Careening Bay, the Bastion du Mât, the Central Bastion, the Harbour Forts, the Arsenals, the Docks, and all the principal buildings of the town, were shaken by the explosions. An equally happy accident saved the Malakoff from destruction: the Russians had laid a conducting wire from the interior of the town to the powder magazine in it, which contained immense stores of ammunition; this wire was discovered in time, and immediately cut. It proceeded from a Voltaic battery in the large barrack in the Karabelnäia suburb, and, but for its accidental discovery, the magazine would have been fired, and its explosion would have spread death and destruction through our ranks.

An account of the applications of physical science, by which such astonishing results are obtained, will not, we trust, be without interest to the reader, and, indeed, it is not for warlike purposes only that this application of electric agency may be employed. The art of mining is continually applied to works of various descriptions: such as the excavation of quarries, railway cuttings, the formation of basins for harbours, &c., &c., and in every case it must always be an important matter to ensure the safety of the persons employed.

Let us first glance over the various methods that have been invented for diminishing the danger of explosions, previous to the application of electric power, many of which methods are still in use. The most common manner of exploding a mine is by means of a long powder-hose enclosed in a wooden case, which is fixed to the frames of the gallery. This is a very certain method when the soil is not very damp, and when the hose has not to remain any considerable time in the earth before the explosion; but it has the inconvenience of filling the galleries with nocuous gasses formed by the ignition of the powder, and of thus rendering them unfit to be entered for several hours after the firing of the charge. Many substitutes for the powder hose, some of them ingenious enough, have been proposed to remove this difficulty: one of these consists of an endless cord, moving in a wooden trough or groove, and conveying a lighted match to the centre of the charge. Another is the rocket, which, containing, as it does, its own motive power, and guided in like manner by a wooden trough, will fire a charge at a great distance in a very short time. Lastly, methods have been invented of firing charges by percussion, as with the musket, the hammer being moved by a lanyard, at a given signal. These different contrivances, however, in practice, are found to be either uncertain or dangerous. The long powder hose, or 'saucisson,' is therefore still in general use for this operation.

It is well known, however, that even this method of firing mines is a source of considerable danger to the labourers employed on the works. There are three causes to which accidents may be attributed: 1st, want of care on the part of the workmen, who, in spite of orders to the contrary, often tamp the mines with iron bars. 2nd, the rapid ignition of the fuze, which does not allow time for the workmen to get to a sufficient distance; or 3rdly, an occasional obstruction or delay in the ignition of the fuze. Of these three causes, the last is that which most frequently leads to accidents. Several charges being generally fired simultaneously, it is impossible to tell at once whether all have gone off, and it may happen that one or more have not exploded, owing to some obstruction in the hose. In this case the workmen, who may have run forward to re-commence their labours, are in great danger should an after-explosion occur, which not unfrequently happens. It has therefore been long a matter for reflection to devise some method of firing mines, free from danger, and at the same time certain in effect.

The application of electricity to the firing of mines has been recommended by scientific men ever since the discovery of the properties of the electric fluid, but it is not generally known that the first idea of this application came from Franklin. That great man, so singular in his outward appearance, was one of the first physical philosophers of his day, without having ever studied physics; he devoted to his experiments only a few months out of his whole life, and was yet able in this short period to immortalize himself by three ever memorable labours; viz., a general theory of electrical phenomena; a physical analysis of the phenomena—up to that time misunderstood—of the Leyden jar; and lastly, the invention of lightning conductors. He owed his success chiefly to his ruling passion for applying the discoveries of science to the common purposes of life. Every discovery appeared to him superfluous and unworthy of attention, which could not, directly or indirectly, be applied to the wants of society. Electricity offered on this account ample field for his benevolent efforts, and every one has heard of the beautiful applications of it which he succeeded in making. As however he has not generally had the credit of being the first to employ electricity in the ignition of powder, we will quote his own words on the subject.

Franklin thus expresses himself in his "Letters on Electricity, dated 29th June, 1751." "I have not heard that any body in Europe has yet succeeded in firing gunpowder by means of electricity. We do it in this way: a small cartridge is filled with dry powder, which is rammed in tightly enough to crush a few grains, two pointed brass wires are then fixed in it, one at each end, so that their two points are not further apart than half an inch at the centre of the cartridge, which is then placed in the circuit of the electrical machine; when the communication is completed, the flame, leaping from the point of one brass wire to that of the other, through the powder in the cartridge, fires it instantaneously."

In this brief notice, written in his quaint style, the American philosopher established the principle of the employment of electricity for distant explosions, and we know that if a metallic wire, surrounded by powder, can be brought to a red heat by the electric fluid, the ignition of the powder may be depended on at any distance.

In Franklin's time, however, the electrical machine was the only source of electricity known. This troublesome instrument, which could not be worked in damp weather without the greatest difficulty, would not do for military purposes*. The old process was therefore still followed for the explosion of mines.

* It should be mentioned, however, that in a series of experiments made at Vienna, in 1855, charges were fired at considerable distances by the electrical machine only, wires covered with gutta-percha being used as conductors.—Tr.

The electric pile, however, discovered by Volta in the year 1800, presented a method of exploding powder, free from the difficulties which had hitherto attached to the employment of electricity in military operations.

When a Voltaic current passes through a metallic wire, no change is apparent in it, provided it is of a certain thickness; but when reduced to a very small diameter, compared with the quantity of the current passing through it, the electric fluid, not finding a free passage for itself, raises the temperature of the wire in its efforts to pass, and the metal attains a red heat, or is even fuzed. It is by this means that the interesting experiments are performed of fusing the most refractory metals, such as platinum, palladium, &c., &c. When reduced to a very fine and short thread, and attached to the two extremities of a powerful Voltaic battery, these metals become red hot and are fuzed. Those metals which resist the greatest furnace-heat may be even vaporized by this means. Gold, for example, if submitted to an experiment of this sort, is immediately resolved into a vapour, and a purple-colored dust may be found after the experiment, resting on surrounding objects; this is nothing but very finely divided gold, which has been condensed from its volatile state.

It is plain then that the apparatus which we have mentioned, composed of a very fine platinum wire, surrounded by an inflammable substance, and communicating with conductors from a Voltaic battery, forms a fuze or priming charge capable of ignition from a distance. As soon as the electric current is allowed to pass, by completing the circuit, the platinum wire becomes red hot, and ignites the powder; and if a fuze of this sort be placed in the centre of the charge of a mine, the mine will explode as soon as the current is established.

In the shape of a Voltaic battery therefore, a much more manageable instrument could be substituted for the electrical machine, which was not sufficiently portable for military purposes. At the time of the first discovery of the Voltaic battery, Gillot, the author of "A Treatise on Subterranean War," remarked on the great advantage to the art of mining that might be gained from the sure and rapid agency of electricity. No attempt, however, was then made to apply it to that purpose. It was not till 1832 that experiments were made in earnest on this subject. They were directed by Lieut. Fabien, in one of our Engineer Regimental Schools. But no practical results were then obtained.* The brass conducting wires were insulated by a covering of resin. But resin formed a very imperfect insulator, for, on account of its extreme brittleness, it was liable to be broken at every inequality of the ground, thus allowing an escape of the electric fluid, which rendered the experiments unsuccessful. Gutta-percha, a remarkably elastic substance, and which possesses very complete insulating power, was imported into France twelve years ago, and the application of it to the service of the electric telegraph is well known. By its means we have been able to establish sub-marine electric telegraphs, which would have been impossible without it. Gutta-percha was found also to possess every quality necessary for the insulation of conducting wires for mines, and experiments were therefore again resumed on this subject.

At Montpellier, in 1845, other experiments were made by the Commanding Officer of the Engineer School. This officer obtained, from the very first, results which have not since been surpassed, and which were soon after made use of by the different armies of Europe.† English miners also applied electric agency to the removal

* The late Colonel Macaulay, R.E., has stated, in his Treatise on Field Fortification, that in 1834 he suggested this application of electricity for firing charges *under water*, and that it was then successfully employed for that purpose.—Ed.

† The Round-down Cliff, near Dover, was blown up in 1844, a year before these experiments at Montpellier took place. (See Vol. VI. Professional Papers, Old Series.)—Tr.

of enormous masses of rock which impeded the navigation of their coast. We shall now proceed to describe the process which was then, and is still, followed in our military schools.

A very fine platinum wire, surrounded by some readily inflammable substance, is placed in the centre of the chamber of the mine to be exploded. This fuze is connected with the conductors of a Voltaic battery, which are carefully covered throughout with gutta-percha. To fire the mine it is only necessary to establish the electric current, that is to say to complete the circuit by connecting the conducting wires with the battery. As soon as the connection is formed, the current circulates, the platinum wire becomes red hot, and the charge is fired.

In military operations, and more particularly in the attack and defence of places, it is often requisite to explode several mines at the same time. In this case each mine is provided with a fuze communicating with the battery. The electric current passes through all these charges simultaneously, provided no part of the wire becomes fuzed.

The system we have described is adopted by most European armies. It is generally to be depended upon at distances not exceeding a few hundred yards, and when not more than two or three simultaneous discharges are required. Eight or ten cells of Bunsen's battery, of a moderate size, suffice in such cases. But if a charge is to be fired at a greater distance it is necessary to increase considerably the number and size of the plates, which must necessarily make the operation more difficult in practice.

On the day of the grand inauguration of the sub-marine telegraph between Dover and Calais, it was proposed to fire a gun on one side of the straits, from a Voltaic battery at the other side, by means of the conducting wire which connected the two countries. This wonderful experiment succeeded perfectly : the electric current, issuing from a battery on the French coast, fired a piece of cannon on the ramparts at Dover. But to ensure the success of this experiment, it was necessary to employ an enormous battery consisting of 400 Bunsen's cells.

Colonel Verdu, of the Spanish Engineers, was a witness, on the English shore, of this experiment. Struck with the inconvenience which resulted from the necessity of employing such enormous Voltaic power for the conveyance of a sufficient current of electricity, to very great distances, he applied himself to the removal of this difficulty, and succeeded in doing so, by combining the ordinary battery with Ruhmkorff's machine. But what is this machine which is known to scientific men by the name of *Ruhmkorff's Coil?*" Although his name is German, M. Ruhmkorff is a scientific instrument maker in Paris, to whom is due the credit of having constructed an ingenious and portable instrument by the help of which the various effects of induced electricity are developed. As the reader will naturally ask what we mean by *induced electricity*, we hasten to satisfy his curiosity.

By induced Voltaic currents, or currents of induction, are meant those electric currents which are momentarily developed in a metallic wire, when the conductor of an active Voltaic battery is brought within a certain distance of this wire. These currents, the existence of which was discovered in our own day by that eminent English chemist Faraday, arise from the power which electricity exerts at a distance on conducting bodies in its neighbourhood. Among other singular properties is that of their existing for a very short time, and of being formed only at the instant of making, and of breaking, the primary current. All instruments, therefore, made for the production of induced electricity, such as those of Clarke and Ruhmkorff, consist of some mechanical system by which the circuit of electricity in a metallic conductor is successively made and broken.

Ruhmkorff's machine,* so called from the name of its able inventor, consists of a large and strong coil, similar in appearance to that of a large electro-magnet; it is laid horizontally on a glass plate which serves to insulate it, and is composed of a thick copper wire, wound a great many times round a cylindrical bundle of iron wire, magneto-electric action having been found to give a singular increase to the powers of induced electricity. Round this thick wire, through which circulates the electric fluid proceeding from a Bunsen's battery, is wound a second very fine wire, 4 or 5 miles in length. By a special contrivance, the current of electricity in the large wire is formed and broken a great number of times in a single second. At each of these interruptions of the current, induced electricity is developed in the fine wire, and may be applied to any required purpose.

One of the effects of induced electricity, arising from its high state of tension, is the production of very powerful *sparks*. It is on account of its great intensity that induced electricity appears to present features different from those of the primary current of a Voltaic pile, although there is in fact no real difference in the principle of these two developments of the same power. It appears to approach more nearly to the so-called *static*, or frictional, electricity, than to the *dynamic* electricity produced by Volta's arrangement.

Electricity of induction has an advantage, as we have before observed, over Voltaic electricity, in the greater ease with which it passes, by means of sparks, over any break in a metallic circuit. And, as in machines constructed for the formation of induced electricity, these currents succeed each other at extremely short intervals, the sparks may be repeated a great many times in a very short period. Thus it has been proved by experiments that very vivid electric sparks may be obtained from induced electricity, and that only a very feeble battery is required for this purpose. Sparks are produced, even through conducting wires of great length, by a single cell of Bunsen's applied to Ruhmkorff's coil.

With this instrument it was found that all the experiments could be repeated which had hitherto been made with the electric machine or with the Leyden jar, and in particular that of the ignition of inflammable substances by the electric spark. These facts being established, M. Verdu conceived the idea of applying this machine to the explosion of mines, for it allowed of a great reduction in the number of cells necessary for firing charges at great distances.

In 1853, M. Verdu and M. Ruhmkorff made, for the first time, some very interesting experiments on the practical applications of the phenomena of induced electricity, which had hitherto been confined to the laboratory. These experiments, made at La Villette, in the workshops of M. Jules Erckman, a telegraphic wire maker, were extremely satisfactory, especially as to the distance to which the electric fluid could travel. Powder was ignited at a distance of 27,000 yards by Ruhmkorff's ordinary coil, an easily inflammable substance being placed between the ends of the conducting wires; and it appears certain that the Russians made use of one of Ruhmkorff's machines, arranged as described, for the explosion of their mines at Sebastopol.

We have said that in his experiments with M. Ruhmkorff, Colonel Verdu made use of very inflammable fuzes, and we shall now proceed to explain what these fuzes were. It must not be supposed that any inflammable substance whatever, such as mealed powder or gun-cotton, can, under all circumstances, be ignited by the spark of the induced current. The heating power of this spark will often be found insufficient for

* For further information on this subject see the article on "Galvanism," in 2nd Edition of British Aide-Mémoire.—Ed.

the explosion of gunpowder: the duration of this spark is *but the millionth* part of a second; now to ignite powder it is necessary that a spark should exist for at least the three-hundreth part of a second. Besides, if the resistance to the passage of the electric current be too great, which may happen from various causes, but chiefly from the too great length of the conducting wire, the spark will be too feeble to fire the charge. It was necessary therefore to construct fuzes very susceptible of heat to make the explosion certain.

This problem was full of difficulties, but chance furnished a solution of it as curious as it was unexpected. During the long series of trials to which the sub-marine cable between Dover and Calais was subjected,* Mr. Statham, the maker of it, discovered an interruption of the circuit in a portion of the conducting wires. On attentive examination he was surprised to find that when the battery was put in action to work the telegraph, a rapid succession of sparks occurred at those points between which the gutta-percha was partially removed.

This was an abnormal phenomenon; for to produce sparks between the ends of conducting wires an electric current is required of very great intensity, far beyond that of the feeble current which suffices for telegraphic purposes. On further study of the circumstances under which the sparks were produced, Mr. Statham discovered that the gutta-percha covering, when stripped from the wire, still retained certain dark-coloured impressions which were conductors of electricity, and it was through these impressions that the sparks were transmitted and propagated, in the same manner as sparks are produced from the electrical machine, by static electricity. Now these impressions turned out to be slight coatings of sulphuret of copper, which is a conductor of electricity, and were produced by the continued contact of the metal with *vulcanized* gutta-percha, that is to say gutta-percha impregnated with sulphur.† Following up this discovery Mr. Statham constructed fuzes called after his name, easily inflammable by the electric spark, and this means of firing a charge by an electric spark had not come much into use before it reached the ears of M. Ruhmkorff, who hastened to employ it in his experiments, and by its means was able to make the explosion of mines certain in every possible case.

There is no difficulty in the preparation of Statham's fuzes. A small piece of copper wire, encased in gutta-percha, such as is now made in great quantities for submarine telegraphic purposes, must be obtained, and the gutta-percha detached from the wire. In this sheath of gutta-percha a small hole is cut, and the ends of the conducting wires leading from a battery are introduced into the sheath, their points being about $\frac{1}{12}$ of an inch apart. The interval between these points is filled with fulminating mercury to make the ignition of the powder more certain. A certain number of these fuzes are prepared beforehand and tested by passing an electric current through them, those which produce the most vivid discharge being kept for use.

By the application of this curious invention Messrs. Verdu and Ruhmkorff have been able to render the explosion of powder certain by means of the spark of an induced current. The labours of M. Verdu had been thus already attended with important results. Instead of the great number of cells of the Voltaic battery formerly necessary to convey sufficient heating power to great distances, two only were now found to be necessary when applied to Ruhmkorff's coil.

In 1854, Captain Savare, of the French Engineers, brought M. Verdu's method to great perfection, by inventing an application of it for the simultaneous discharge of any number of mines. The following is the extremely ingenious method adopted by

* See page 151, Vol. IV., of this Series.—Ed.

† The process of vulcanizing, or impregnating with sulphur, is no longer in use.—Tr.

Capt. Savare for firing a number of charges in succession with Ruhmkorff's coil. The conducting wire from one pole of the coil has branches leading to each of the charges: these branches converge again, and unite with a single wire leading to the other pole, or the earth may be made to do the duty of the return wire. These arrangements having been made, the whole of the first electrical wave from the machine passes* through the branch which offers least resistance to its passage, and the corresponding charge only is ignited; but if the effect of the explosion can be made to destroy the circuit through the first branch, the current of electricity, on its second passage, must take another road; a second explosion will therefore take place and a second circuit will be broken. The currents will thus go on flying through branch after branch with great rapidity, until every charge has been exploded. Thus the success of the operation depends entirely on the efficacy of the means adopted at each explosion to destroy the circuit in which it occurs. To ensure this result Captain Savare made the fine metallic points between which the spark is produced of an easily fusible metal. On the ignition of the powder these points are melted and dispersed, leaving nothing but an insulating envelope of gutta-percha which is quite incapable of affording a passage for the electric current.

Experiments were made with this new apparatus at Grenelle in 1854, in presence of General Sallenave, Director of Fortifications, of M. Schuster, Commanding Engineer of the army of Paris, and of several officers of rank. The two principal experiments were: 1st, the explosion of ten small mines by means of a single wire from the coil; 2nd, the explosion of a single mine, at a distance of 760 yards, by a single wire. The wires were insulated from the ground and supported on small wooden posts: the signal for firing was made by three taps of the drum. All these experiments succeeded perfectly, the two mines exploded at the concerted signal, and an interval of not more than a second could be perceived between the two discharges.

We should not omit to mention that M. Verdu, on his return to Spain, directed his attention to the same object, and was equally successful in effecting the simultaneous explosion of a great number of charges. His experiments were made on the Engineer exercising ground at Guadalaxara, at a distance of 3,280 yards from the charge, and with a *single* insulated conducting wire extended in a straight line, with one Bunsen cell, and making use of Statham's fuzes charged with fulminating mercury, M. Verdu succeeded in exploding simultaneously 10 charges placed in the same circuit at 3,280 yards from the instrument. The method he employed is different from that of M. Savare and we shall proceed to explain it as briefly as possible.

When it is required to fire a great number of charges at the same time, M. Verdu distributes them in groups which have each a separate circuit, and are fired successively. If, for instance, twenty charges are to be fired, they would be divided into 5 separate groups. The 5 fuzes of each group are connected by a single wire, one end of which is buried in the ground, and the other brought close to the coil. By successively bringing one pole of the coil into contact with the ends of the four wires, which is done almost instantaneously, twenty simultaneous explosions may be made at great distances, at 600 yards, for instance. But M. Verdu found no limit either to the distance at which a single charge could be fired or to the number of charges that could be fired simultaneously. Thus, in an experiment made at a distance of 3,800 yards, the explosions of the mines were so nearly simultaneous that the noise appeared to be that of a single discharge.

It is not for military purposes only, as we have already said, that electricity may be applied to the explosion of mines. In the execution of all works which involve the

* This theory appears to be incorrect, as it is well known that the electric fluid will distribute itself amongst all the branches in the inverse proportion of the resistances offered.—Ed.

necessity for mining, the method of firing by electric agency offers great advantages. We cannot establish this fact better than by recalling to mind the beautiful results lately obtained in the works of the harbour of Cherbourg by the system of electrical explosion arranged for this special purpose by that able man of science M. Th. du Moncel, whose researches we have more than once called to our aid in our review of the industrial applications of electricity.

For the last 15 years, large works have been in course of execution in the harbour of Cherbourg. A basin, more than a thousand yards in length and 65 feet deep, is being cut out of the solid rock. But for some time the works, directed by the Engineers of the roads and bridges *(Ingénieurs des ponts et chaussées)*, did not progress sufficiently to satisfy the government. Much time had been lost, much powder and money spent, and but very little done. In 1854, the Government, hoping that private interest would attain the desired end more surely and rapidly than official duty, determined to put the works out to contract. Two Engineers, Messrs. Dussaud and Rabattu, who had already shewn their skill at Algiers and at Marseilles, undertook the enterprise.

The first act of Messrs. Dussaud and Rabattu was to abandon the system of mining which had hitherto been followed by the government officers; they rightly considered that the small charges previously used, of from 4 to 7 lbs., did not shatter the rock sufficiently for subsequent excavation, and that charges of several thousand pounds of powder should be used, as at Algiers.

The success of this system of large charges could not be ensured except by the employment of electricity, and the contractors therefore requested M. du Moncel to organize some easy and infallible system of firing by its agency. The system proposed by him has succeeded even better than was expected, inasmuch as it is at present an established fact that the employment of electricity in firing mines has the advantages of ensuring the safety of the workmen employed, and certainty of results, as well as of obtaining an increase of the force or mechanical effect of the powder, resulting from the simultaneousness of the explosion, and lastly of saving 60 or 70 per cent. in the cost. This system then has been adopted for the works at the port of Cherbourg. Once a month the contractors fire a set of mines, consisting generally of six charges, which, in an instant, remove 65,000 cubic yards of rock, while but a single report is heard. This sight always attracts a large number of sight seers to the military port of Cherbourg.

We shall now show how M. du Moncel's system differs from that adopted by his predecessors. The object desired to be attained was the simultaneous explosion of several enormous mines, each containing 8,800 pounds of powder, and the advantageous effect of these large charges depends entirely on the simultaneous action of the partial subterranean disturbances produced by their explosion. To ensure this simultaneous action, M. du Moncel had recourse to the processes so successfully employed by Messrs. Verdu and Savare; his improvements were merely modifications of their systems.

It has been mentioned that in the experiments carried on in Spain by M. Verdu, and in France by M. Savare, from 6 to 8 charges had been fired in one circuit. In order to ensure a greater certainty of ignition, M. du Moncel preferred dividing the whole number of charges into pairs, each pair having its own circuit; and to obtain the simultaneous explosion of each of these sets of two charges, he adopted a method which appears to be more certain in its effects than that employed by M. Savare. For the required purpose, it would have been sufficient to have fixed on to a slip of wood or gutta-percha as many metallic plates as there were sets, or pairs, of charges, each plate being connected with the wire leading to one set. By rubbing quickly across these plates a metal bar, connected with Ruhmkorff's coil, nearly simultaneous currents of electricity would be produced in the several circuits, each metallic plate conveying the current to its own pair, on coming in contact with the metal bar. M. du Moncel however preferred a less simple but equally effective arrangement. Instead of a slip of wood he used a thick wheel of gutta percha put in motion by clockwork, and bearing on its circumference 5 metal plates, separated from each other by intervals of ¾ of an inch. A spring pressing on the circumference of this wheel is connected with one of the poles of Ruhmkorff's coil.

The plates themselves communicate by means of metal bars, attached to the two plane surfaces of the wheel, with 5 friction springs* attached to the 5 wires of the set. Lastly, a catch, intended to restrain the spring when wound up, allows the wheel to be set in motion at any moment.

The action of this machine may easily be understood: when the wheel is set in motion, it presents in succession, to the first mentioned spring, the plates on its circumference; but as these plates, by their connection with the other springs, successively complete the different circuits, the electric current is transmitted through them all in an inappreciable interval of time.

We shall conclude this paper with a few remarks on the manner of constructing the enormous mines so successfully used at Cherbourg.

†Each of these mines generally consists of two cubical chambers, the sides of which are 3 or 4 yards long, excavated at a depth of about 38 feet below the surface of the rock, and filled with powder. A shaft about 3 feet square is first sunk, and from the bottom of this shaft two galleries about 5 feet high are driven, to a length of 16 feet. The chambers are formed at the extremities of these galleries. The powder is not thrown loosely into the chambers for fear of its getting damp during the long task of tamping, but is placed in gutta-percha sacks, hermetically sealed, and is provided with an exploding fuze. Each bag contains 4,400 pounds of powder. When the loading is completed, and the two ends of the fuze are attached to the conducting wires, the galleries are built up solidly with stone and mortar, and the shaft is filled in with earth, so that the mines are connected with the surface of the ground only by the conducting wires, which are built in with the masonry.

If we appear to have dwelt too long on the subject of the last-named electrical machines, it is because we are convinced that they will one day be extensively applied. Their employment indeed for the explosion of mines is only one of many applications of Ruhmkorff's coil. This instrument might be employed, for instance, with perfect certainty by the Artillery, under various circumstances. A battery of several guns might be simultaneously discharged by it; fire-ships may be ignited at a distance; sunken ships destroyed, such as the Russian fleet in the harbour of Sebastopol, and sub-marine mines exploded. Under all circumstances the employment of the machine we have just described would be of inestimable advantage, from the security it affords to those employed on any of these various duties.

M. du Moncel, to whom we are indebted for an excellent pamphlet, lately published, on Ruhmkorff's coil, remarks that the same system might be advantageously adopted in the ordinary firing of artillery. The vent through which artillery is now fired is the cause of endless accidents to the gunners, for the air entering through the vent, allows substances to remain burning in the chamber of the gun, by which the next charge of powder is liable to be exploded. With the electric process the vent would be unnecessary, and a fuze would be substituted, which could be so arranged as to be kept fixed in the gun, and be always available, which arrangement would put an end to accidents of this description.

For fireworks, lastly, and for all siege works where simultaneous explosions are required, firing by electricity cannot be surpassed.

* Ressorts-frotteurs.

† A similar system has been employed at Holyhead, see Paper XII., Vol. 6, of this Series.—Ed.

Extracts from the 2nd Volume of the "Exposé des Applications de l'Électricité par M. Th. du Moncel."

Translated by Lieutenant Colonel Bainbrigge, Royal Engineers.

Application of Electricity to the Explosion of Mines.

An entire chapter of our first volume was devoted to this mode of employing electricity, which is so curious and at the same time so important. The reader will recollect the curious phenomenon, not explained when that was written, of *sparks* produced by means of a dynamic current passing along conductors covered with gutta-percha.

This phenomenon had suggested to Messrs. Brunton and Statham the idea of their mode of firing charges, and the construction of their fuzes. Why was it that the electric current, passing along a wire covered with a perfectly insulating substance, could traverse a break in this wire, and produce a spark, when the wire was surrounded by a case of gutta-percha which those gentlemen described as "galvanized?"—This was the question to be answered.—Now Mr. Faraday, by making extensive experiments upon currents passing along wires covered with gutta-percha, was easily enabled to reply to it. It appeared from his experiments that if a wire covered with an insulating substance is plunged into water, or is enveloped in a conducting substance like tin foil, for instance, a statical reaction takes place between the current passing through the wire and the conducting substance, which not only paralyzes the movement of the current, but gives to it a statical nature, so that it can produce a spark. The principal condition then which is required to render effective the physical re-action, which is the basis of the arrangements made by Messrs. Brunton and Statham, is that the conductor cased in gutta-percha should be also covered by a conducting substance.

The second part of the question, viz.: the part performed by the galvanized gutta-percha, in giving facility for overcoming the "solution of continuity" experienced by the current, may be explained by the experiment on the induction-sparks produced in bodies of secondary power of conduction, which I published on the 26th December, 1853, and from which it appears that a body of secondary powers of conduction, being interposed between the electricities developed on the two sides of a solution of continuity in an induction-current, facilitates the discharge, and is easily ignited. The gutta-percha in Statham's fuzes, stated as galvanized, and which were in fact impregnated with sulphuret of copper, as we now know, merely acted as a secondary conductor between the two electricities accumulated at the two extremities of the wire at the break, and must, consequently, facilitate the discharge.

The part performed by the secondary conductors in Statham's fuzes having been fully recognized, M. Ruhmkorff first, then M. Verdu, and lastly M. Savare, endeavoured, each in his own way, to perfect them, in order to apply them to induction-currents. They abandoned the small glass cases, and substituted a little gutta-percha cover, cut with a slope and impregnated with sulphuret of mercury, and they ended by replacing the gunpowder itself by fulminate of mercury.

Having been requested by the contractors for the extension of the harbour of Cherbourg to organize for them an apparatus for exploding charges, which would be economical and easily managed, and which would be especially capable of being constructed without difficulty by provincial workmen, I first thought of substituting the mechanical action of electricity for its physical action, in order that Daniels' batteries might be employed ; for these, as is well known, continue in activity for months without requiring attention, and their expense is trifling. I therefore had an apparatus prepared by means of which the fire was communicated to fuzes or trains of powder by a chemical match acted upon solely by the current; with this I could operate at a considerable distance, by means of very fine wire, if necessary not insulated, and I had the advantage, by sending the current back from one apparatus to another, of being able to act upon as many charges in succession as might be considered desirable. This apparatus only costing 25 francs for each, there was great economy in employing it, especially for works where it was required for *daily* use: But that was not the main object, *complete simultaneousness* of explosion was desired in using charges of 4,000 kilogrammes of powder, since all the useful results of such *volcanoes*, the effect of which is however only subterranean, depend principally on simultaneousness in the commotions occasioned by the explosions. I was therefore obliged to renounce my first system, at least for this kind of mining, and to return to that of M.M. Ruhmkorff and Verdu, (above mentioned) which I modified a little in order to render its application more easy and more certain.

Extracts from an Account of the Application of an Electric Friction-Apparatus to the Firing of Mines by the Austrian Imperial Engineers, Written by MAJOR VON EBNER, on the Staff of that Corps.

Translated by Lieut. Colonel Bainbrigge, R.E.

Orders having been received at the Imperial Engineer Academy, at the beginning of the year 1853, to propose a mode of exploding charges by electricity, to be employed by the Imperial Engineers, an opportunity was afforded for undertaking a thorough investigation of the capabilities of different electrical machines, which had been much wanted.

The splendid effects of Ruhmkorff's induction-apparatus, which had just been made known, proved that the solution of the problem might be expected by the use of electricity, but it was not thought that this had yet been actually effected. The combinations of fragile materials and exciting fluids, or complicated rotation-machines, appeared very objectionable for use in the field, and the probability of the apparatus becoming injured caused much anxiety, as this was very likely to arise both from external causes and from the destruction of the insulating layers, produced by too powerful currents under circumstances when no remedy could be applied.

During three years experiments were carried on, which were often repeated, and the results have completely fulfilled the expectations entertained, for the method which will be here described is now in use by the corps of Engineers, and has been applied to many useful purposes.

The electrical machine consists of two disks formed of polished glass, 12 inches in diameter, and 4 lines thick, revolving on a common horizontal axis, the interval between them being $1\frac{1}{2}$ inches. Friction is produced by their contact with cushions, fixed so that they may be kept, by means of springs, slightly pressing against the disks.

For the Leyden jar such a form was chosen as would permit of its being easily replaced anywhere. It is of a cylindrical shape, and is 15 inches high and 6 in diameter. It is protected by flannel, and fixed in a case formed of lacquered tin, being screwed on to an iron plate, which is connected with the friction apparatus. The outer surface of the Leyden jar, the area of which contains 276 square inches, is therefore also connected with those portions of the machine.

The charging is effected by means of a steel point, which projects one inch into the space between the disks, and can be pushed into an arm of the conductor. The latter is inserted into a plate of hard caoutchuc, which forms the cover of the Leyden jar, and is connected with its inner surface by means of two chains. The machine is always covered, when in use, by a case, the sides of which are made of thick leather, and the top of tin. A small stove is also attached beneath it, so as to dry the air inside when necessary.

The effects of this machine were, under all circumstances, as great as were required. Their is no difficulty in maintaining its efficiency; the insulation of the Leyden jar is secured by means of a varnished covering, and the only points requiring attention are the drying of the disks, which are liable to get damp, and keeping the friction apparatus in a proper state. Although the weight of the apparatus is so little as to allow of its being carried by one man for short distances, it is desirable that it should be rendered more portable, so as to adapt it better for military purposes; and this can easily be effected, a smaller and less powerful one having been made, the weight of which is only 20 lbs.

There appears to be reason to hope that the parts formed of glass may be replaced by others made of hard caoutchuc. This material seems likely to be much employed in electrical machines on account of its perfect power of insulation, its freedom from damp, its durability, and its capabilities for moulding; but, unfortunately, it cannot yet be procured in sufficient quantity, or sufficiently good, for the purpose.

To connect the machine with the charges, brass wire was employed, the weight of which was 18·6 lbs per mile. It was supported on posts placed at intervals of 50 to 80 paces, and was covered with gutta-percha when it was to lie in water or earth. The ignition of the charges was effected by means of substances which could be easily fired by an electric spark; of these fulminate of mercury was found to possess that property in the highest degree, and the danger of using it is much diminished by keeping its harmless constituents separate until actually required. It was carefully placed in the cartridge, so as to surround the ends of two copper wires firmly fixed in their places by means of rosin poured in around them, the interval between the wires being about $\frac{1}{48}$th of an inch. The fulminate of mercury was covered by a piece of card, over which some gun-cotton was fixed, and the cartridge was then closed by a cork.

The capabilities of this apparatus for exploding charges at great distances, and under water, have been proved by many experiments. The greatest distance at which a charge was exploded was $18\frac{1}{2}$ miles, and in this case one charging of the Leyden jar, obtained by three turns of the disks, sufficed to explode a cartridge exactly in the same manner as if the shortest wire had been employed. In this instance the wire extended from the machine to the cartridge and back; but there is scarcely any doubt that the result would have been the same if the wire had been extended in one straight line, and the current had been allowed to return through the earth.

On many occasions 50 charges, connected in one circuit, were exploded simultaneously, in one case 36 being fired in this way after having been placed in water 6 feet deep for 20 hours before; and it may be observed that thrice, during the experiments in the months of September and December, the machine remained exposed to very heavy rain.

NOTE.—At the end of the interesting Paper on this subject by Captain Ward, R.E., in the 4th Volume of the Professional Papers, will be found a note by Major General Portlock, in which he draws attention to the use of the electric spark in igniting charges of gunpowder. The friction-machine used by the Austrian Engineers, and described above, acts in that way, and there is reason to believe that by means of the spark great *certainty* may be obtained, which is manifestly the most important qualification of any system to be employed in military mining. A series of experiments have therefore been made by the Ordnance Select Committee, at Woolwich, with Ruhmkorff's machine, as well as with large magnets, for the purpose of testing their powers of igniting charges by means of the spark.

The magnets were of the horse-shoe form and 22 inches in length, and were arranged by Mr. Henley in a light cart or barrow so as to form a pile $6\frac{1}{2}$ inches high; and those portions of the armature opposite to the piles of the magnets were surrounded by large coils of well insulated wire, and fixed on pivots so that the circuit could be broken by pressing upon a lever.

Mr. Abel, chemist to the War Department, has succeeded in making fuzes which are ignited by the electric spark with the greatest certainty; they consist of two small copper wires, $\frac{1}{16}$th of an inch in diameter, fixed at a distance of about $\frac{1}{30}$th of an inch apart, and enveloped in gutta-percha whilst the latter is in a soft state, so that they cannot afterwards be disturbed, the ends of the wires being surrounded by a very sensitive and conducting composition; and the following are the results of the experiments made with them.

With Ruhmkorff's machine 4 fuzes connected in one circuit were fired through a wire 2 miles long and an earth connection about 500 yards long. With Henley's magnets 4 fuzes in one circuit were fired in 17 out of 20 consecutive trials; but only two were fired *with certainty* by their means. The obstacle to the firing of numerous charges simultaneously has been found by Mr. Abel, after a long experimental enquiry, to be that the composition employed cannot be made sufficiently conducting in its nature to favor the passage of the current through several small interruptions of the circuit, and at the same time sufficiently sensitive to be ignited with certainty.

Ruhmkorff's machine is very portable, requires only three cells of Mc.Callan's battery to work it effectually, but its insulators are delicate and liable to injury.

The magnets require no battery and are not affected by the state of the atmosphere, nor are they likely to get out of order, but their weight is considerable, and they cannot, in the form hitherto tried, be relied upon for firing more than 2 or 3 charges simultaneously.

Each of these machines requires only one person to fire the charges by merely moving a handle, but an apparatus has been applied to Ruhmkorff's machine for firing a number of charges in very rapid succession, which requires a second operator. This consists of a board having a number of brass plates let into it flush with its upper surface, to each of which one of the wires leading to the charges is attached, and a bar provided with a handle being fixed to the board by a pivot at one end, the wire from the battery is attached to the bar, which has a strong spring screwed to its lower surface in such a position as always to press firmly on the brass plates. By turning this bar quickly round on the pivot as a centre, the circuit is rapidly completed between the machine and each of the charges in succession, and thus a close approximation to the simultaneous firing of many charges may be obtained with a very moderate power. This might perhaps be advantageously applied to the magnets also if the armature were made to revolve and thus afford a rapid succession of sparks.

In conclusion, it may be useful to state that Mr. Armstrong, the eminent Engineer, is devising, at Professor Wheatstone's suggestion, a small *hydro-electrical* machine which it is hoped will be applicable to military purposes, as a considerable amount of electricity is obtained from jets of steam, and the apparatus required is very simple and easily managed.—ED.

PAPER XXII.

Notes on the Russian Works on the North Side of Sebastopol, between the Forts Sivernaia and Constantine.

By LIEUT. G. GRAHAM, Royal Engineers.

These batteries being merely intended to act against shipping, have generally been built along the sea coast, as shewn in the annexed sketch. All the batteries, with the exception of Nos. 1, 8, and 10, and the lower tier of No. 9, are placed on the top of the cliffs and have a command over the sea of from 80 to 100 feet.

Although batteries thus placed appear to have little to fear from the direct fire of ships, yet in some cases, as in No. 2 battery, the parapet is 29 feet thick, and is generally from 22 to 25 feet thick measured along the sills of the embrasures.

The whole of these batteries are carefully protected from enfilade and reverse fire by enormous traverses, in which are magazines. &c., constructed with all the solidity usual in the other Russian bombproofs. In their old batteries the Russians appear to have generally revetted the cheeks of the embrasures throughout with gabions, but in their more recent and best constructed batteries, (as Nos. 2, 3, 4, and 5), they only use 4 gabions in each cheek, which are placed nearly perpendicularly, firmly staked, and plastered over with clay, which was done probably as much to retain the earth in the gabions as to conceal the embrasures. The gabions, being upright, project somewhat inside the interior crest, thus leaving a smaller opening at the top of the embrasure and giving more cover to the muzzle of the gun. The remainder of the cheeks of the embrasures, as well as the exterior slope, is usually revetted with a mixture of earth and seaweed in horizontal layers which appears to stand well. The interior slopes were frequently revetted with the same material, but they generally appear, probably from a want of gabions, to have preferred sun-dried bricks, composed of clay mixed with seaweed, and this appears to be their best revetment ; for a moderate height it is built perpendicular, but it has generally a slight inclination. Sod revetments were also extensively used for the traverses and interior slopes.

The guns, now dismounted, are all 32 and 42 pounders ; the majority appear to have been mounted on Naval carriages, and to have been run up with breeching tackle, two posts being sunk so as to stand vertically against the interior slope and serve as a purchase to the tackle, and they also retain the planks employed as a revetment to the genouillère.

The platforms are of the same pattern as our old gun-platforms, splaying to the rear and spiked. The traversing guns are generally long 32 pounders, about 10 feet 6 inches long. They fire either through embrasures or " en barbette," and traverse about 20°. Those in the Wasp Battery traverse round the whole circle. The traversing platforms for the former are secured by a pivot of wrought iron to a solid wooden frame, in which two grooves are formed under the front angles of the platform, in each of which three shot are placed to facilitate the traversing of the latter, which are supported by them and by a cross sleeper at the rear.

Fort Sivernaia.

This is an octagonal bastioned fort, the fronts of which have very short flanks *f*, *f* Fig. 1, traced perpendicularly to the faces of the bastions, AB, CB, the dimensions of which are shewn in the sketch approximately.

The rampart is not continued along the flanks of these bastions, but extends across their gorges, forming retrenchments to each, and stairs lead from the latter into the ditch at the rear of each bastion, which is bounded at each end by a wall having an embrasure below and loopholes above, forming the two flanks of the bastion, the bridge across the ditch affording access to these loopholes.

In two of the bastions the interior of the retrenchment has been cut away to form bombproofs, &c., and in one of these, (the southern bastion), the walls of a large defensible barrack have been commenced, as shewn by the letters *r*, *r*, *r* (Fig. 1), apparently with the intention of making that bastion independent of the others.

The guns fire " en barbette," except on the eastern and north-eastern faces, which have 7 or 8 embrasures respectively, provided with rope mantlets.

The ground falls towards the north, and the terreplein of the northern face has been raised very high, to obtain command; it is however very narrow and would not mount more than three or four guns, unless a great amount of labour were expended upon it. Owing also to the enormous parapet at this part, and the steepness of the exterior slope, the scarp wall has given way in many places, so as to form practicable breaches. The scarp walls have also given way in some other parts of the fort, and attempts have been made to repair them. They are roughly constructed of unhewn masonry, with clay, I believe, instead of mortar, and appear to be without counterforts.

The barracks in the interior, consisting of small houses in each angle, have been rendered altogether untenable by the French vertical fire from the South side.

G. GRAHAM, Lieut. Royal Engineers.

June 26, 1856.

References to the Accompanying Sketch.

No. 1.—20 gun battery of 32-prs., firing on the sea, 8 guns traversing and firing through embrasures, and 12 guns not traversing.

No. 2.—Indented battery of 42-prs.

23 guns on naval carriages .... } firing on the sea.
4 ,, on traversing platforms. }
6 ,, firing into the gorge of Fort Constantine.
—
33 total.
—

No. 3.—Wollakoff battery. Machicolated square masonry tower, surrounded by an earthen parapet, mounting eight 42-pr. guns traversing over a complete circle: also four 4 gun batteries firing on the sea.

No. 4.—11 gun sea-battery (42 pounders.)

No. 5.—10 gun battery, of redan trace, having 2 guns on the right flanking the low part of the sea coast to the eastward: also a small 4 gun sea-battery to the right.

No. 6.—Battery for land-defence. 3 guns on the left fire on the sea and flank a trench which runs to the edge of the cliff, and 10 other guns flank the sea-coast and point inland. The right flank is joined with Fort Sivernaia by a trench.

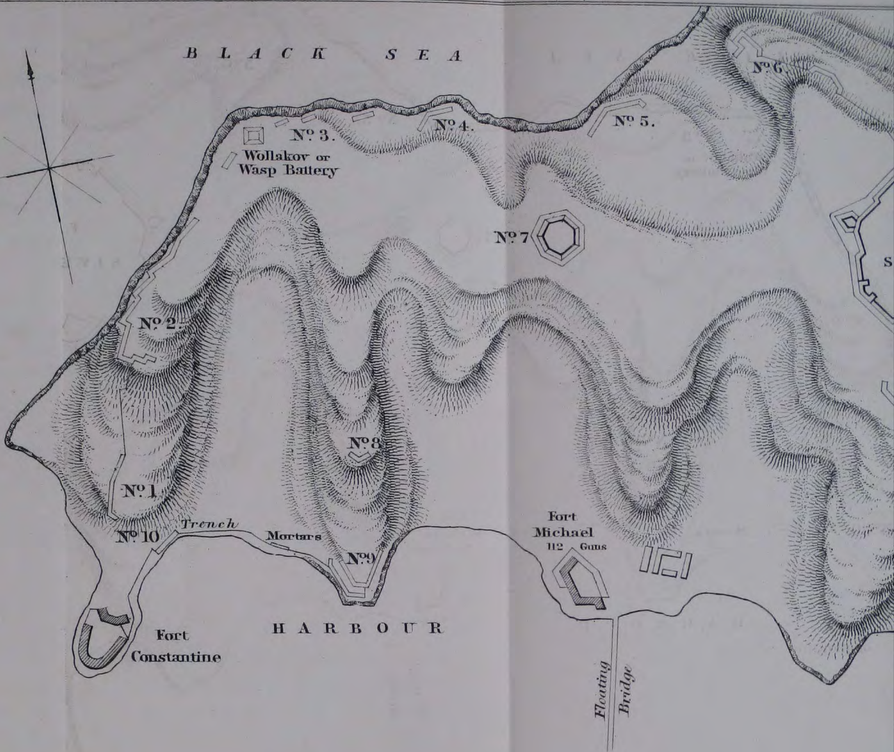
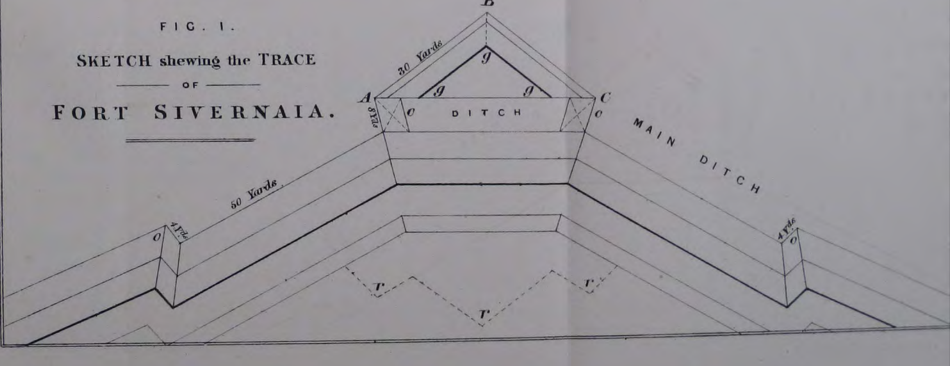


FIG. I.

SKETCH shewing the TRACE OF FORT SIVERNAIA.



No. 7.—Heptagonal redoubt mounting seven 32-prs., one traversing in each angle. These guns fire "en barbette," and are protected by small weak merlons thrown up on the top of the parapet. In the centre of the redoubt is a look-out. This work is for land defence, and the fire of two of its guns would sweep the bay to the west of Fort Michael.

No. 8.—Redan-shaped battery of 6 guns, 3 firing on the Karabelnaia, and 3 on the French attack.

No. 9.—Large battery mounting 33 guns. The left flank is indented and has 8 guns firing through embrasures, and 1 traversing gun flanking the shore and Fort Michael. The right flank has two tiers, mounting 13 guns in the upper tier and 11 in the lower, all traversing long 32-prs. flanking the shore and Fort Constantine, and defending the entrance to the harbour.

No. 10.—A battery of eight 32 prs. flanking the shore and right flank of No. 9, with which it is connected by a trench. Half way between it and No. 9 is a battery of three 10-inch mortars.

PAPER XXIII.

Tables shewing the Results of Experiments on the Penetration of Rifle Bullets into various Substances, carried on at the Royal Engineer Establishment at Chatham, in 1858,

By CAPTAIN WHITMORE, Royal Engineers,

Under the direction of COLONEL SANDHAM, R.E.

The arms used in these experiments were the Enfield Rifle, of the pattern of 1853, denoted by the letter E in the table, using the ordinary bullets introduced in 1855,

denoted by the letters.. .. .. .. E. O.
and the same with steel points, denoted by.. E. S.
also the Lancaster rifled carbine, denoted by L.
with ordinary bullets .. .. .. L. O.
and the same with steel points .. .. L. S.

The penetration is given in inches, and is measured from the point of impact to that where the head or point of the bullet rested.

Material fired at.	Distance fired from in yards.	Description of weapon and ball.	Number of shots fired.	Penetration in inches.			
				Greatest.	Least.	Mean of the whole.	Mean, rejecting the greatest and least.
EARTH, light, sandy, formed into a small parapet, and rammed lightly.	200	L. O.	6	15 0	12·0	13·3	13·25
	-	E. O.	6	17·0	11·0	13·83	13·75
	-	L. S.	5	18·0	10·0	14·0	14·0
	-	E. S.	5	17·0	12·0	14·8	15·0
	20	L. O.	12	*31·0	8·0	15·0	14·1
	-	E. O.	5	19·0	12·0	15·2	15·0
	-	L. S.	4	18 0	12·0	15·0	15·0
	-	E. S.	6	18·0	6·0	14·5	15·75
ELM, eight 1-inch boards placed close together, (in good condition.)	200	L. O.	5	4	3	3·4	3·33
	-	E. O.	5	4	3	3·4	3·33
	-	L. S.	5	4	3	3·7	3·83
	-	E. S.	5	4·5	3	3 9	4
	20	L. O.	10	4	3	3·55	3·56
	-	E. O.	10	4	3	3·8	3·875
	-	L. S.	5	4 5	3 5	4·05	4·083
	-	E. S.	5	4·5	4	4·4	4·5
ELM, solid, firing *with* the grain, (in good condition.)	20	L. O.	4	6	5	5·5	5 5
	-	E. O.	4	6 25	5·75	6	6
	-	L. S.	4	6	5 5	5 81	5·875
	-	E. S.	4	6 5	6	6·375	6·5
ELM, eight 1-inch boards (very dry), placed close together.	200	E. O.	4	3	2·5	2 82	3
	200	E. S.	4	4	2 5	3·37	3 5
	175	E. O.	4	3	3	3	3
	175	E. S.	4	4	3·25	3·56	3·5
	150	E. O.	4	3·5	3	3·1	3
	150	E. S.	4	4	3·5	3·75	3·75
	125	E. O.	4	4	3·5	3·75	3·75
	125	E. S.	4	4·25	4	4·06	4
	100	E. O.	4	4	4	4	4
	100	E. S.	4	4·5	4·25	4·37	4·37
	75	E. O.	4	4·5	4	4·25	4·25
	75	E. S.	4	4·5	4·5	4 5	4·5
	50	E. O.	4	4 5	4·5	4·5	4·5
	50	E. S.	4	5 25	5	5·12	5·12
ELM.—Two 3-inch planks close together, (in good condition).	200	L. O.	5	4	3	3·6	3·66
	-	E. O.	5	4	4	4	4
	-	L S.	9	5·5	4	4·44	4·36
	-	E. S.	9	6	4	4 89	4·86
	20	L. O.	5	4·6	3·19	4·26	4·41
	-	E. O.	5	4 24	4·13	4·25	4·29
	-	L. S.	5	5·5	4	4·7	5
	-	E. S.	5	5 5	4	4·9	5
OAK, solid, a well seasoned log about 15 inches square, firing across the grain.	200	L. O.	6	2·5	2	2·25	2·25
	-	E. O.	6	2·5	2	2·42	2·5
	-	L. S.	6	3	2	2·5	2·5
	-	E. S.	6	3	2	2·58	2 62
	20	L. O.	5	3·25	2·25	2·6	2·83
	-	E. O.	5	2·75	2·5	2·7	2·75
	-	L. S.	4	4·25	3·25	3·62	3·5
	-	E. S.	5	4·25	2·75	3·4	3·33

* This bullet appears to have passed through a loose part.—ED.

Material fired at.	Distance fired from in yards.	Description of weapon and ball.	Number of shots fired.	Penetration in inches. Greatest.	Least.	Mean of the whole.	Mean, rejecting the greatest and least.
OAK, solid, and well seasoned, but not the same log as the above (being rather newer), firing *with* the grain.	20	L. O.	4	2.75	2·5	2·56	2·5
	-	E. O.	4	3	2·5	2.81	2·87
	-	L. S.	4	3·5	3·25	3·37	3·37
	-	E. S.	4	3·5	3	3·25	3·25
OAK.—3-inch plank, in good order, with four 1-inch elm boards behind it.	200	L. O.	5	3 passed through oak and 2 elm boards. 2 did not pass through oak.			
	-	E. O.	5	4 passed through oak and 2 elm boards. 1 did not pass through oak.			
OAK.—3-inch plank, with another 3-inch plank behind it.	200	L. S.	6	5·5	3·5	4·66	4·75
	-	E. S.	6	5·5	4·5	5	5
	20	L. O.	5	3·25	2·75	3	3
	-	E. O.	5	4	2·75	3·5	3·58
	-	L. S.	5	4	3·5	3·7	3·66
	-	E. S.	6	4·5	2·75	4·08	4·31
ASH.—Two 3-inch boards, close together, (in good condition).	200	L. O.	5	3	2·5	2·75	2·75
	-	E. O.	5	3	2·5	2·75	2·75
	-	L. S.	6	3·5	2·5	2·92	2·87
	-	E. S.	6	3·5	3	3·17	3·12
	20	L. O.	5	3	2·75	2·87	2·87
	-	E. O.	5	3	2·75	2·87	2·87
	-	L. S.	5	3	3	3	3
	-	E. S.	5	3·5	3	3·17	3·12
ASH.—Solid, firing *with* the grain.	20	L. O.	4	3·5	3	3·25	3·25
	-	E. O.	4	4	3·5	3·69	3·62
	-	L. S.	4	4·5	3·75	4·06	4
	-	E. S.	4	4·5	4	4·25	4·25
BEECH.—Two 3-inch planks placed close together, (in good condition).	200	L. O.	5	3·25	2·5	2·75	2·62
	-	E. O.	5	3·25	2·5	2·75	2·66
	-	L. S.	6	4	2·75	3	2·81
	-	E. S.	6	4	3	3·33	3·25
	-	L. O.	5	3	2·75	2·85	2·83
	-	E. O.	5	3	2·5	2·75	2·75
	-	L. S.	5	3·5	2·5	3·1	3·17
	-	E. S.	5	3	2·75	2·85	2·83
BEECH—Solid, firing *with* the grain.	20	L. O.	4	5·25	4	4·56	4·5
	-	E. O.	4	5	4·5	4·62	4·5
	-	L. S.	4	5·25	4·5	4·87	4·87
	-	E. S.	4	5·5	4·75	5·12	5·12
PINE. Twenty 1-inch deal boards close together, (good and just sawn).	200	L. O.	6	10·5	7·5	8·83	8·75
	-	E. O.	6	11·5	7·5	9·17	9·0
	-	L. S.	6	12·5	9·5	10·92	10·87
	-	E. S.	6	13	10	11·83	12
	20	L. O.	7	14·5	9	12·86	13·3
	-	E. O.	7	14·5	9·5	12·86	13·2
	-	L. S.	9	17	10	14·55	14·21
	-	E. S.	8	18	10	15·12	15·5
PINE, solid, firing *with* the grain.	20	E. O.	8	14	6·5	9·94	9·83
	-	E. S.	8	16	7	12	12·17

Materials fired at.	Construction.	Distance fired from in yards.	Description of weapon and ball.	Number of shots fired.	Penetration.
SANDBAGS, established pattern, filled with light sandy earth and built up as the interior slope of a parapet.		200	L. O.	6	Extreme penetration in 2 headers 10 inches.
		-	E. O.	6	Do. do. 10 do.
		-	L. S.	6	Do. do. 12 do.
		-	E. S.	6	Do. do. 12 do. One passed through a stretcher.
		20	L. O.	4	None passed through.
		-	E. O.	4	One passed through a stretcher only.
SAP-ROLLER, established pattern, stuffed and just made. Diameter of external gabion, 4′ 0″; Ditto internal ditto 2′ 6″; Thickness of stuffing...... 0′ 9″		20	L. O.	5	All through the first 9 inches of brushwood, but not further.
		20	E. O.	5	Do. do.
FASCINES, ordinary, of green wood and just made, 9 inches in diameter.		200	L. O.	5	All through, and 5″ into earth behind.
		-	E. O.	5	Do. 6″ do.
		-	L. S.	5	Do. 6″ do.
		-	E. S.	5	Do. 6″ do.
		20	L. O.	5	Do. 7″ do.
		-	E. O.	5	Do. 8″ do.
		-	L. S.	4	Do. 9″ do.
		..	E. S.	4	Do. 9″ do.
GABIONS filled with light earth, not rammed, but having stood 3 weeks it had settled down. External diameter 2 feet.	Brushwood	20	E. S.	3	None passed through.
	Tyler's sheet iron ..	20	E. S.	3	Do.
	Serg. Major Jones's sheet iron hoop.	20	E. S.	3	Do.
	Sebastopol hoop iron.	20	E. S.	3	Do.
	Tyler's as above....	20	E. S.	4	Greatest penetration 12″
GABIONS filled with light earth, not rammed, but thrown in just before firing.	Brushwood	50	E. S.	10	None passed through.
	Tyler's.....	50	E. S.	10	Do.
	Jones's, as above ..	50	E. S.	10	Do.
	Sebastopol hoop....	50	E. S.	10	Do.

NOTE.—From the results of these experiments we may conclude that, at a range of 200 yards, the penetration into wood of bullets fired from the Enfield Rifle is greater than that of those fired from the Lancaster Carbine, (in some cases by $\frac{1}{9}$th), the same ammunition being used for both; and that the penetration into wood, at 200 yards, of the steel pointed bullet is greater than that of the ordinary bullet, (in some cases by $\frac{1}{6}$th.)—ED.

Materials fired at.	Distance fired from in yards.	Description of weapon and ball.	Number of shots fired.	Penetration.
ROPE MANTLET, newly made, of good, but not new, 4″ rope, bound at front and back with $1\frac{1}{2}$″ cross ropes, and connected by spun-yarn sewn through the mantlet, on the model of those used in the Redan at Sebastopol, size 4′ 0″×3′ 3″, weight 139 lbs., or 10·69 lbs. per square foot. It was made with great care, the 4″ vertical ropes of one face being worked in to fit the hollows between those on the other face.	200	L. O.	10	6 passed through. 4 were stopped and fell underneath.
ROPE MANTLET made as a "sword-mat," (suggested by Sergeant-Major J. Jones, R.E.,) of $1\frac{1}{2}$″ rope, kept together with spun-yarn. An oar-blade is used in making this mat to wedge it up and tighten the rope—4 thicknesses were placed together, giving a weight of 8 lbs. to the square foot.	200	L. O.	5	All passed through, being, from the appearance of those found in in the Butt, very little flattened or injured

NOTE.—The experiments lately made by the Ordnance Select Committee at Woolwich with rope mantlets prove that no protection against the Enfield rifle bullet is afforded by one of 14lbs. to the square foot at 300 yards, but that one of 17lbs. to the square foot gives security at 200 yards, and one of 20lbs. to the square foot at 100 yards; whilst it requires one of $27\frac{1}{2}$lbs. to the square foot, consisting of 3 vertical and 2 horizontal layers of $4\frac{1}{2}$ inch rope, to give protection at 50 yards. The experiments with mantlets proposed by Sir George Sartorius, consisting of a series of steel plates, 3 inches wide, riveted horizontally to a hide, so that each may overlap that below it $\frac{1}{4}$ inch, showed that if the thickness of the plates is $\frac{1}{8}$ inch, (the mantlet weighing 9lbs. per square foot,) it is not proof against the Enfield rifle bullet at 150 yards; but that if the plates are $\frac{1}{4}$ inch thick, security is afforded at 50 yards. These therefore afford the same protection as the thickest rope mantlet, though their weight per foot is less than one-half of the weight of the latter.

The mantlet formed of steel plates and hides was proposed to be suspended on posts for boat service, and is capable of being *rolled up* when not in use, but it must be observed that it is much heavier than the 'homogeneous' iron plates referred to in the next table, which can be more easily propped up, and were also proof against the Enfield Rifle bullets at a range of 50 yards, the weight of the former being 13 lbs. per square foot, whilst that of the latter is only $7\frac{5}{12}$ lbs. per square foot.—ED.

Material.	Number.	Thickness.	Weight.	Weight per square foot.	Distance fired from in yards.	Description of weapon and ball.	No. of shots fired.	Effect on the Plate.
'HOMOGENEOUS' IRON PLATES, manufactured by Messrs. Shortridge, Howell, & Jessop of Manchester, two numbered A1 and A2, and two with prepared faces numbered B1 and B2. Size of all, 6 feet by 2 feet.	A1	$\frac{1}{4}''$	lbs. 129	lbs. $10\frac{3}{4}$	200	E. O.	4	Indented very slightly.
					150	E. O.	4	Do. do.
					100	E. O.	4	Indented slightly.
					50	E. O.	4	2 hit on same spot, indented $\frac{1}{2}''$, but no crack produced. 2 indented $\frac{1}{4}''$.
					20	E. O.	3	2 hit same spot without cracking the plate, the 2nd ball remaining buried in the metal, indented $\frac{1}{4}''$. 1 indented $\frac{1}{4}''$.
					200	E. S.	4	Indented $\frac{1}{16}''$ without any crack.
					150	E. S.	4	Do. $\frac{1}{8}''$ do.
					100	E. S.	4	Do. $\frac{3}{16}''$ do.
					50	E. S.	4	Do. $\frac{3}{16}''$ do.
					20	E. S.	4	Do. $\frac{1}{4}''$ do.
	A2	$\frac{3}{16}''$	lbs. 89	lbs. $7\frac{5}{12}$	200	E. O.	4	Indented about $\frac{1}{6}''$.
					150	E. O.	4	Indented about $\frac{1}{6}''$.
					100	E. O.	4	Indented a little deeper than at 150 yards.
					50	E. O.	4	1 hit a spot previously struck at a longer range and indented $\frac{1}{2}''$. 3 indented $\frac{1}{4}''$.
					20	E. O.	4	Indented about $\frac{1}{4}''$, but no crack.
					200	E. S.	4	Indented about $\frac{1}{4}''$.
					150	E. S.	4	3 indented $\frac{3}{8}''$. 1 struck a spot previously hit by E. O. at 50 yards, and by E. O. at 20 yards, it tore the plate and passed through.
					100	E. S.	4	Indented about $\frac{3}{8}''$, no crack.
					50	E. S.	4	Indented about $\frac{3}{8}''$, no crack.
					20	E. S.	4	Indented about $\frac{1}{2}''$, no crack.
Iron Plate with "prepared face."	B1	$\frac{1}{4}''$	lbs. $130\frac{1}{2}$	lbs. $10\frac{4}{16}$	200	E. O.	4	Indents hardly perceptible.
					150	E. O.	4	Indented about $\frac{1}{16}''$.
					100	E. O.	4	Do. do.
					50	E. O.	4	Indented $\frac{1}{8}''$.
					20	E. O.	4	Do. do.
					200	E. S.	4	Indents hardly perceptible.
					150	E. S.	4	Indented $\frac{1}{16}''$.
					100	E. S.	4	Indented $\frac{1}{10}''$.
					50	E. S.	4	Indented $\frac{1}{8}''$.
					20	E. S.	4	Indented $\frac{3}{16}''$.

Material.	Number.	Thickness.	Weight.	Weight per square foot.	Distance fired from in yards.	Description of weapon and ball.	No. of shots fired.	Effect on the Plate.
The plate reversed, to expose the back instead of the prepared face.	B1	-	-	-	200	E. O.	4	Indented very slightly.
					150	E. O.	4	Indented $\frac{1}{16}$"
					100	E. O.	4	Do. do.
					50	E. O.	4	Indented $\frac{1}{8}$".
					20	E. O.	4	Indented $\frac{3}{16}$".
			lbs.	lbs.				
Iron plate with "prepared face."	B2	$\frac{3}{16}$"	98	$8\frac{1}{6}$	200	E. O.	4	Indented $\frac{1}{8}$".
					150	E. O.	4	Do. $\frac{3}{16}$".
					100	E. O.	4	Do. $\frac{3}{16}$".
					50	E. O.	4	Do. $\frac{1}{4}$".
					20	E. O.	4	Do. $\frac{1}{4}$" (no cracks.)
					200	E. S.	4	Do. $\frac{3}{16}$".
					150	E. S.	4	Do. $\frac{1}{4}$".
					100	E. S.	4	Do. $\frac{1}{4}$"
					50	E. S.	4	3 indented $\frac{3}{8}$", 1 cracked the plate, (probably from there being a flaw in it.
					20	E. S.	4	Indented $\frac{3}{8}$" (no crack).
The above reversed, to expose the back.	B2	-	-	-	200	E. O.	4	Indented $\frac{1}{4}$".
					150	E. O.	4	2 indented $\frac{3}{8}$", 1 indented $\frac{1}{16}$, and 1 indented $\frac{1}{4}$".
					100	E. O.	4	Indented $\frac{3}{8}$".
					50	E. O.	4	Indented $\frac{1}{2}$".
					20	E. O.	4	Indented $\frac{1}{2}$" (no crack).
			lbs.	lbs.				
ORDINARY BOILER PLATES each 3 ft. by 2 ft.	1	$\frac{1}{8}$"	34	$5\frac{2}{3}$	200	E. O.	3	All three bullets passed through this plate.
	2	$\frac{3}{16}$"	41	$6\frac{5}{6}$	200	E. O.	3	All three bullets passed through this plate.
	3	$\frac{1}{4}$"	59	$9\frac{5}{6}$	200	E. O.	4	2 bullets passed through. 2 do. did not pass through but indented and cracked the plate.

The conclusions drawn by Captain Whitmore from the experiments recorded in the above tables, as well as from others previously made, are the following:—

1. The lightest plate which has been found to resist the effect of the Enfield rifle bullet is Messrs. Shortridge and Co.'s Homogeneous Plate numbered A 2, $7\frac{5}{12}$lbs. to the square foot, and $\frac{3}{16}$ inch thick, which answered perfectly well.

2. Another plate, by the same makers, with "prepared face," numbered B 2, $8\frac{1}{6}$lbs. to the square foot, and $\frac{3}{16}$ inch thick, is of about the same strength as the above, only one crack or rent having been produced in it, which appears to have arisen from a flaw.

3. Cammell's plate, $8\frac{8}{9}$lbs. to the square foot, and $\frac{3}{16}$ inch thick, (No. 2) answered pretty well, having only been cracked once; but the indents are much deeper than those in the two above mentioned, and it cannot be considered proof.

4. Saunderson's, $9\frac{1}{16}$lbs. to the square foot, and $\frac{3}{16}$ inch thick, (No. 8,) does not answer at all.

5. Cammell's 9lbs. to the square foot, and $\frac{5}{32}$ inch thick, (No. 1) does not stand the test at all.

6. Boiler plates, even $\frac{1}{4}$ inch thick and $9\frac{5}{6}$lbs. to the square foot, are not proof at 200 yards.

The difference of resistance between the prepared and unprepared faces appears to be very slight.

The charge made by the makers for the lightest plates which are proof is,—

	£	s.	d.
For Shortridge's A 2 (6 ft. by 2 ft.)	2	0	2
Ditto........ .. B 2 (6 ft. by 2 ft.)	2	8	3

The weight of the large sap-mantlet at present in use, 6 ft. by 4 ft. and mounted on wheels, is 549lbs., the plates weighing 10·125lbs. per square foot.

The weight of the same, if formed of Shortridge's homogeneous plates $\frac{1}{4}$ inch thick would be, at 10·44lbs. per square foot,

Plates, (2 in front and bar over joint)........	259·02 lbs.
Fittings of wrought iron	172·34 ,,
	431·36 lbs.

Thus the total weight would be reduced by 117·64lbs.

Note.—As Shortridge's plate (A 2), only $\frac{3}{16}$ inch thick, and $7\frac{5}{12}$lbs. to the square foot, "answered perfectly well" it might probably be used advantageously for the sap-mantlet, in which case the weight of the latter may be still further reduced, viz., to about 350 lbs., or $\frac{7}{11}$ths of the present weight.—Ed.

ERRATA.

Vol. IV., p. 154, line 16, for 'a' read 'and.'

Vol. V., p. 49, line 50, omit 'being.'

" " 50, " 23, substitute $\frac{u}{m'}$ for $\frac{M}{m'}$.

" " 50, " 32, for 7 read 8.

" " 52, " 2, for 'elasticity,' read 'liquidity.'

Vol. VI. In plate opposite page 120, add a Tower at the centre of line D.