# PREFACE.

THE duties, both military and civil, which are imposed upon Officers of Engineers, are so various in their character, and require so extensive an acquaintance with both practice and theory, that any individual officer can hardly be expected, during the course of his service, to make himself completely master of all the details of the subjects which may be brought under his notice. He must of necessity refer to the experience of others; and it is one of the advantages of the Corps of Royal Engineers, and of other bodies similarly circumstanced, that no jarring interests, or professional jealousies, can interfere to prevent one officer giving to another, when required, every advice and assistance in his power. It may, and indeed does, however, often happen, that an officer, when called upon for his opinion and advice, or ordered to execute some new work, may not have it in his power to refer to the experience of others for assistance: occasions of this kind have frequently given rise to suggestions for the publication of a professional work, in which should be embodied the experience of individuals; and which, being circulated among the Officers of the corps at large, would serve, in some measure, to remedy the inconveniences which arise from the mode in which they are scattered over the world, and which puts a stop to that freedom of intercourse, and interchange of information, which would otherwise take place amongst them. At the same time, however, that this effect is produced, some advantage is gained by the difference in character and amount of the practical information found in different parts of the world, and which advantage will appear in a more prominent point of view, should means be taken to make the information generally known. Conscious of this, a meeting of several Officers was held at the Royal Engineer Office, for the purpose of considering the details of a plan proposed for the attainment of the above objects; and the following Resolutions were adopted and approved by the Inspector-General of Fortifications:

1st.—That this Meeting entirely coincides in the opinion expressed in the Prospectus laid before them, as to the utility of the circulation of scientific and professional information among the Officers of the Corps of Royal Engineers.

2nd.—That Lieutenant Denison be requested to take upon himself the task of correcting the Press, and conducting the publication of the various Papers which may be sent for circulation.

3rd.—That Messrs. Cox & Co. be requested to open an account, which they will credit with the amount of the Annual Subscriptions of the Members, while they will debit it with the amount of the bills for Printing, &c., which they will pay when certified by Lieutenant Denison.

4th.—That the Subscription shall not exceed Ten Shillings annually, to commence from the present date, but hereafter, to become due on the first of January every year.

5th.—That the Officers of the East India Company's Engineers be invited to contribute to the collection of Professional Memoranda, as they form a corps, in some measure, connected with the Royal Engineers, pursuing the same objects, educated at the same establishment, and having similar interests as far as the present Publication is concerned.

6th.—That an Annual Meeting shall take place on the First of February every year, at Twelve o'clock, when a statement of the Receipts and Expenditure shall be laid before the Subscribers.

The following Rules for conducting the Correspondence, and selecting Papers for Publication, appear well adapted to the objects which the Meeting have in view.

Every paper sent for circulation, will be published as soon as there are funds sufficient for such a purpose in the hands of the Agents: should more papers be sent in than can be published immediately, a selection must be made, and in such case, the following Rules will guide the Officer in charge of the Publication, in giving precedence to one paper over another.

1st.—Papers containing facts shall be preferred to mere speculative essays.

2nd.—Subjects of general application shall be preferred to those of a local and more confined nature.

3rd.—Among subjects of general interest, precedence shall be given according to the date of their reception.

The Officer in charge of the Publication will take the earliest opportunity of communicating with those Societies, Institutions, or Individuals, from whom he may be likely to obtain information on professional subjects; and he will communicate to the Subscribers, not only the positive information he may thus procure, but also the hints, suggestions, and questions, on any subjects of scientific inquiry which may be brought before him, whether or no they have direct reference to subjects purely professional. He will also request to be allowed to examine the Reports and Plans in the Royal Engineer Office, with the view of selecting, and laying before the Inspector-General, such as he may think likely to prove interesting to Officers of Engineers; and should the Inspector-General approve of the publication of the Reports and Papers on any particular subject, he will arrange and embody into one Paper, all that can be gathered on that subject, not only from the Documents in the Office, but also from any sources of information which may be open to him.

Upon the requisition of a certain number of the Subscribers, he may propose questions for discussion, which will be circulated with the rest of the Papers, and the replies will form a part of the next volume of notes published.

It will not be requisite to draw any very precise line by which to regulate the character of the communications which Officers may wish to make, or which it may be desirable to publish. Should the Officer in charge of the Publication feel a doubt as to the propriety of publishing any Paper, he shall be allowed to postpone it for the consideration of the next General Meeting. And he shall be at liberty, with the approval of the Author, to insert in the different scientific periodicals any Papers which, from their peculiar character, or connexion with particular branches of science, may merit a more extended circulation than the narrow limits of the present Publication can afford.

(Signed) C. G. ELLICOMBE,
Brigade-Major, Royal Engineers.

(Approved) F. W. MULCASTER,
Inspector-General of Fortifications.

# CONTENTS.

# INTRODUCTION.

In laying before my brother Officers this volume, the first fruit of our joint labours, I trust I shall not be thought to overstep the limits of my duty as Editor, if I prefix the few following introductory remarks.

The object of the present work is to collect, methodise, and arrange, the large mass of professional information which is at present disseminated among the individuals of the corps of Engineers; and to combine it with that derived from other sources; thus enabling every officer to avail himself not only of the experience of his fellows, but also in some measure of that of all those whose occupations and duties are similar to his own.

A work of this nature has long been a desideratum in the corps of Engineers: several attempts have been made at different times to establish something of the kind; but from various causes these attempts have hitherto failed.

Those who are aware how much has been done in many departments of science by a well-digested system of co-operation, can best appreciate the advantages we should derive from the adoption of a similar system. The number and variety of the duties upon which we are employed, while they present many obstacles to the attainment of an accurate knowledge of our profession, seem at the same time to point out a system of co-operation as the surest mode of overcoming them.

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

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

Unless this be the case, we may indeed prolong the existence of our work for a few years, by drawing upon the stores that have been already laid up; but these must soon be exhausted, and the common routine duties of the Corps will hardly afford materials for an annual volume.

Where then, it may be asked, are these materials to be found? I answer, in the detail of the numerous experiments to which every branch of the service should give rise; in the investigation of various subjects intimately connected with both the military and civil branches of our profession; and finally, in the study and application of sciences, which, although not directly professional, have much in common with our duties, and which, while useful and interesting in themselves, will serve to draw closer those bonds which unite us with other scientific bodies in this country.

To these points, therefore, our attention should be drawn; and I hope and trust that many among the junior branches of the Corps, who are now just commencing their professional career, will omit no opportunity of cultivating that knowledge, without which their services will be comparatively valueless, and which, they may rest assured, will amply repay them for any exertion they may make in the pursuit.

There is pleasure in the mere exercise of the intellectual faculties; there is pleasure in the acquisition of knowledge for its own sake; but when knowledge is combined with utility, when it is available for the benefit of others, the pleasure is infinitely increased. I press these remarks with the more earnestness upon my brother Officers, from the knowledge I have of the state of education at the Military Academies in this country. It cannot be concealed, that when compared with similar institutions in other countries, these, as places of scientific instruction, are grievously defective; and it therefore behoves those who, after passing the ordeal of a nominal examination, have received their commissions, not to delude themselves with the idea that they possess all the elementary knowledge which their profession requires. Far from it; labour and study will be requisite to enable them to perform satisfactorily their ordinary duties; and this should be their first consideration: but this labour and study brings with it its own reward, not only as it enables them to perform their duties efficiently, but as it is the stepping-stone to the cultivation of those sciences which open a wider range to the intellect, extend their sphere of usefulness, and which, by occupying the mind and improving the faculties, tend eventually to make them better officers and better men.

W. DENISON,

*Lieutenant, Royal Engineers.*

# PROFESSIONAL PAPERS

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## I.—*On Assaults. By Lieutenant-Colonel* Reid, *Royal Engineers.*

Our attention has been carried back to the assaults executed during the sieges of the two forts of Salamanca and of Burgos, in 1812, from reading the general account given of these operations in the fifth volume of Colonel Napier's 'History of the Peninsula War:' and as assaults are the most difficult as well as the most important operations in a siege, we are desirous of explaining, as well as we can, the causes which led to the failure of some, and the success of others.

The more these operations are studied, the firmer will be the conviction, that in assaults, as in every other military operation in war, success chiefly depends upon conducting the troops employed in the best possible order, availing ourselves in the best manner of discipline and organization, to make one simultaneous and united effort, with superior numbers, at the point of attack.

It is difficult to preserve good order in assaults: but in proportion as this difficulty increases, so does the necessity for maintaining it increase also: for it may be considered as an axiom in war, that the greater the danger, the greater the necessity for good order.

Some of the examples cited in the fifth volume of the 'History of the Peninsular War,' are strikingly illustrative of this principle.

The first assaults in point of date, were those of fort San Gaytano, one of the detached forts at Salamanca, besieged in June 1812.

We give a plan and section, which is taken from the plate of 'Jones's Journal of Sieges,' that we may be better understood.

The two detached forts of San Gaytano and La Merced, were very ingeniously constructed from convents; so that, by filling up some rooms and supporting others by timber, from the roofs, which were removed, good bomb-proof quarters were obtained in the forts themselves, as well as casemates for flanking the ditches. The ditches, which were deep and broad, were formed between convent walls, which with little alteration served as scarps and counter-scarps; and the glacis was formed of the ruins of the many houses which had been levelled round these forts.

It will be seen, by the plan and section, that a deep valley separated the two detached forts of San Gaytano and. La Merced, from the principal work of San Vicente.

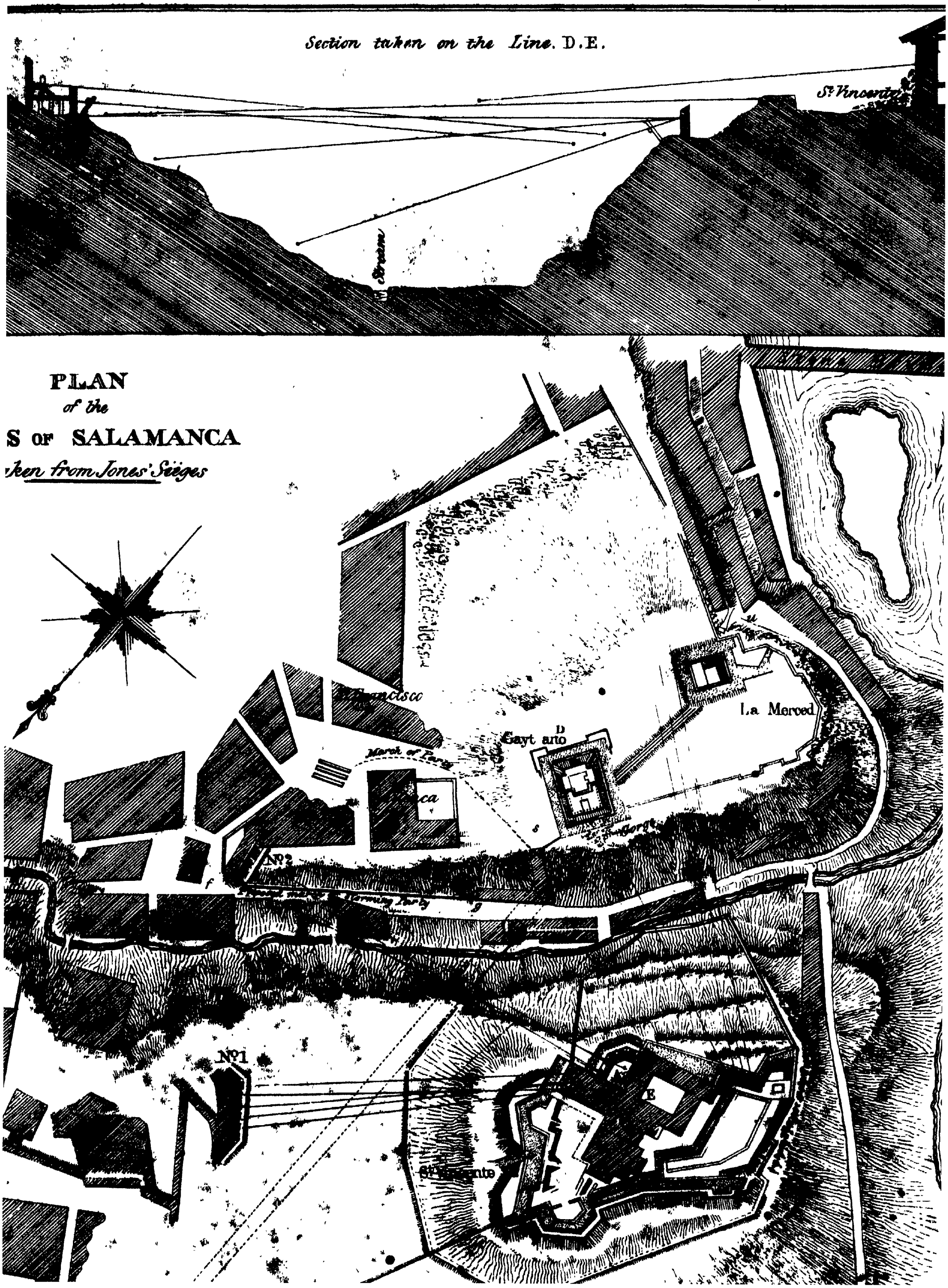
It will be also seen, that a street led down this valley, and that the houses of it, with some intervals, continued past the rear of the two detached forts, as far as the ancient city wall. This street had not been destroyed; and by it the besiegers were enabled to get down in the night, to the very corner of the rear wall of San Gaytano without any risk; and when once there, they were sheltered from all the three forts.

On the 23rd of June, the palisades at the foot of the rear wall had been broken by an oblique battery which fired across the valley, and its stone parapet was a good deal deranged. The assault, which failed, was ordered to take place at 10 o'clock at night. The moon shone bright.

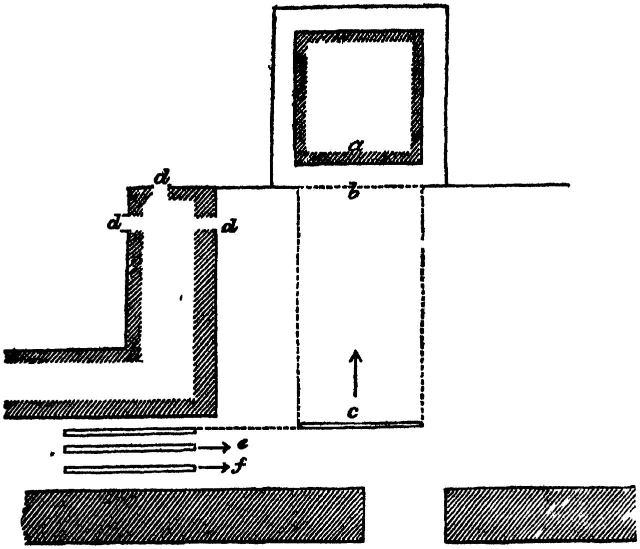
An officer of engineers had been named to guide the head of the assaulting party two days before, and he spent the greater part of these two days in examining the approaches.

The opinion he came to was, that the party should be led down the street in the valley, and formed in it close to the corner of the wall to be stormed. He had prepared twenty ladders to be carried to the same spot, which number would have covered the whole extent of the rear wall to be attacked: and as he proposed that, after these ladders should be planted, under the protection of a firing party in the surrounding houses, the troops for the assault should be led straight out, division after division, until the head or right of each should be opposite the further end of the enemy's rear wall, and the rear, or left of each division, should be opposite to the nearest end of the enemy's wall, the divisions being in succession turned to their left, they would march up the slope below the gorge of the enemy's work in good order, and escalade with a front of twenty men, if all ladders were planted.

Had the assault been executed in this manner, there is no doubt but that it would have been successful. The annexed wood-cut will render this more distinct.



Section taken on the Line. D.E.
St Vincente
Stream
PLAN
of the
S OF SALAMANCA
ken from Jones' Sieges
S. Francisco
La Merced
D
Gayt ano
March of Party
Gorge
No 2
No 1
E
St Vincente




*a*, the gorge of fort San Gaytano.
*b*, the palisades broken.
*c*, the first company led out.
*e*, *f*, second and third companies.
*d*, *d*, *d*, narrow doors in the group of ruined buildings through which the first assaulting party passed.

Three companies were ordered for the assault, and they paraded under cover of the college of Cuenca marked in the plan. When it was proposed, however, to take the twenty ladders prepared, the officer appointed to lead received the most peremptory order from General Bowes to take but four; and when he indicated the covered street as affording the best approach, he was not listened to, but received a concise and direct order to lead the party from the spot where they were formed, across a corner of the glacis, and through a group of ruined houses between the end of the glacis and the street alluded to above. The general went out himself, with the officer who was to lead, to the foot of the glacis, and pointed out doorways in these ruined houses, by which the party could get at the gorge.

Through these ruins and narrow door-ways, the party was accordingly led; and, as is recorded in 'Jones's Journal of Sieges,' two ladders were planted against the wall; the only two which were brought forward, the men with the other two being killed or wounded. Some carpenters with axes came also to the foot of the wall, and set to work to widen the breaches in the palisades: but not ten men of the storming party followed. One of the door-ways through which they had to file, man by man, was (see plan) within twenty yards of the direct fire of the enemy's parapet; and after the leading files had passed, a check took place, and not another man could be got to pass through this dangerous door-way.

Whilst this check took place in the front, the centre and rear of the party hurried over the corner of the glacis, where they were exposed to a deadly fire, and sheltered themselves in the group of ruined houses, where they became crowded in great confusion. The officers throughout had made the most gallant exertions to bring their men forward. In despair they assembled near this door-way, to consult what they could do; and it was agreed to re-form their men; and after placing an officer on each side of the door-way, to force the men through it.

The whole were accordingly forced through; but instead of keeping to their left, and going up to the wall and the two ladders raised against it, they turned to the right and fled by the street in the valley. The ladders were left standing against the wall.

General Bowes did not actually lead the assaulting party, although he must have been upon the glacis, and his voice was heard at the moment when the officers were making the second effort to lead on the men. He appeared then to be near the south-east angle of the fort, and in front of the Cuenca college; and it is probable that about this moment he was killed.

The cause of this failure requires no comment.

When the second assault took place, the party was formed as was recommended for the first. The head of each division was led straight out from its place of cover, filing parallel to the breach until it was opposite to the furthest end of it, when the command "Left, turn," was given; and the three divisions, exactly equal in front to the breach itself, were marched in, in succession, at a little more than open column distance from each other, and in excellent order, a firing party of the Portuguese caçadores keeping the fire under from the surrounding houses. The besiegers made no resistance against this second assault. The rear wall had been battered down, and the garrison would have surrendered, had it not been contrary to their military code to do so, without standing one assault after a breach had been effected. It took place in the daytime, when assaults are most likely to be well conducted.

The next assault, in point of date, was that of storming and carrying the hornwork on the height of San Miguel at Burgos. We quote below, the description, both of Colonel Napier and of Sir J. T. Jones, of this hornwork of San Miguel, as well as their accounts of the assault. Sir J. T. Jones was himself present.

Colonel Napier describes it thus:—"The Napoleon battery commanded every thing around it, save on the north, where, at the distance of 300 yards, there was a second height, scarcely less elevated than that of the fortress. It was called Hill of San Michael, and was defended by a large hornwork, with a hard sloping scarp twenty-five, and counter-scarp ten feet high. This outwork was unfinished, and only closed by strong palisades; but it was under the fire of the Napoleon battery, was well flanked by the castle defences, and covered in front by slight intrenchments for the out-pickets. The French had already mounted nine heavy guns, eleven field-pieces, and six mortars or howitzers in the fortress; and as the reserve artillery and stores of the army of Portugal were also deposited there, they could increase their armament."—*Napier's History*, vol. v. p. 263.

Sir John Jones describes the hornwork thus:—"The situation of this fortified post (the castle) was very commanding, excepting on the side of the hill of San Michael, the summit of which, at less than 300 yards distance, is nearly on the same level with the upper works of the castle, but separated from them by a deep ravine. This height was occupied by a hornwork of large dimensions, the front scarp of which, hard and slippery, twenty-five feet in height, stood at an angle of 60°, and was covered by a counter-scarp ten feet in depth. The branches were not perfect, and the rear had been temporarily closed, on intelligence of the fall of Madrid, by an exceedingly strong palisading. No part of the front or branches were palisaded. The whole of the interior of the hornwork was under fire of the battery on fort Napoleon, and its branches were well flanked from the works of the castle."—*Jones's Journal of Sieges*, vol. i. p. 296.

We quote also, from both works, the descriptions of this assault. Colonel Napier says:—"The batteries so completely commanded all the bridges and fords over the Arlanzan, that two days elapsed ere the allies could cross; but on the 19th, the passage of the river being effected above the town, by the first division, Major Somers Cocks, supported by Pack's Portuguese, drove in the French outposts on the hill of San Michael. In the night, the same troops, reinforced with the 42d regiment, stormed the hornwork. The conflict was murderous. For though the ladders were fairly placed by the bearers of them, the storming column, which, covered by a firing party, marched against the front, was beaten with great loss; and the attack would have failed, if the gallant leader of the 79th had not, meanwhile, forced an entrance by the gorge.

exemplified: yet, in the daytime, the powerful flanking cannon of the castle would have disordered the columns of attack in their approach; and this, at the time, was supposed to be the chief reason for assaulting in the night.

The slope was of rammed earth very neatly scarped with the spade. There was no palisading, excepting at the gorge where Major Cocks escaladed. But these palisades were from twelve to fifteen feet high, made, some of entire, and some of split poplar trees from the avenues of the city; but all of a thickness, which could not be cut down by axes during an assault; and it was observed, that even the cannon shot from the castle, which frequently struck them during the siege, seldom cut them down.

We shall quote again the same authors for their descriptions of the second assault at Burgos, which failed. Colonel Jones says:

"With a view of abridging the attack, and to save the troops from unnecessary fatigue, Lord Wellington determined to make an effort to carry the exterior defences of the castle by escalade, and form a lodgment on the top of the wall. The escarpe wall, at the point selected, was from twenty-three to twenty-five feet in height, built on a steep bank, but without any reveted counter-scarp; and midnight was the hour fixed for the enterprise.

"ARRANGEMENT FOR THE ESCALADE.

"A party of 400 men, provided with five ladders, to be carried by six men each, was directed to march into the hollow road, *h i*, running from the suburb of San Pedro, parallel to the wall to be assaulted, about sixty yards from its foot, in the bottom of which they would find themselves in security from the fire of the place. Half the party, that is 200 men, to take post near the top of the bank, *r k*, and arrange themselves in line, so as to fire over the bank against the work to be assaulted, with the view of preventing the garrison from mounting the thick earthen parapet, and using their bayonets.

"The other 200 men were to be divided into sections of twenty men each; and on ladders being reared against the wall, an officer with the first section was to mount to the assault. That accomplished, the next party of twenty to advance from under the bank, and follow up the ladders: these to be succeeded by other twenty men; and so on successively until the whole 200 should be in. The firing party on the bank then to become a working party, and pull down a portion of the wall to form a ramp up. For this latter purpose, and to make a secure communication to the spot from the trenches, a more considerable working party was held in readiness by the engineers, with gabions, fascines, &c. To favour this escalade, a Portuguese battalion was ordered to assault the same line by its left flank on the side of the town, at a point, D, where the defences are of a weak profile, and where the garrison only kept a small guard, not yet having any suspicion of its being the intention to direct the principal effort against the south end of the castle.

" EXECUTION OF THE ASSAULT.

" The attack of the flank defences by the Portuguese battalion never came to any thing like a serious attempt. They were checked whilst advancing by a fire from a guard-house on the line, and did not enter the ditch. The escalade in front, therefore, even if correctly executed, would not probably have had more than a momentary success. As it was, the men with five ladders reached the walls, and reared them almost unopposed: but the main body, although the ground was perfectly open, advancing on a front of only four men, had lengthened out so considerably before they reached the point of contention, that on the garrison opening their fire, much confusion was created, by the efforts made to close up the ranks; and, in consequence, the firing party never took post on the bank, but the whole pushed forward together into the ditch. Several gallant attempts were made to ascend the ladders, and some of the assailants each time gained a momentary footing, but were as often bayonetted down; after which the garrison mounted on the top of the parapet, and in addition to a fire of musketry, threw over a quantity of 4 lb. shot, and much burning composition, which caused many of the men's pouches to explode.

" Major Laurie, 79th regiment, the commanding officer, being killed, and the party being composed of detachments from different regiments, (a measure replete with ill for night movements, or hazardous enterprises,) there was some difficulty in ascertaining who was the senior officer, and the whole remained for above a quarter of an hour under the destructive efforts of the garrison, 'unable to advance, unwilling to retire, and having given up all hope of success.' At length, the point of seniority being determined, and all the officers agreeing in the necessity of withdrawing, the order was given, and the remnant retired, leaving nearly half their numbers killed, or lying wounded under the wall."—*Jones's Journal of Sieges*, vol. i. p. 306.

Colonel Napier's account is thus stated:

" In the night, the first battery was armed with two eighteen-pounders and three howitzers, and the secret battery within the hornwork was commenced; but Lord Wellington, deviating from his first plan, now resolved to try an escalade against the first line of defense. He selected a point half way between the suburb of San Pedro and the hornwork; and at midnight 400 men, provided with ladders, were secretly posted, in a hollow road fifty yards from the wall, which was from twenty-three to twenty-five feet high, but had no flanks: this was the main column, and a Portuguese battalion was also assembled in the town of Burgos, to make a combined flank movement on that side."

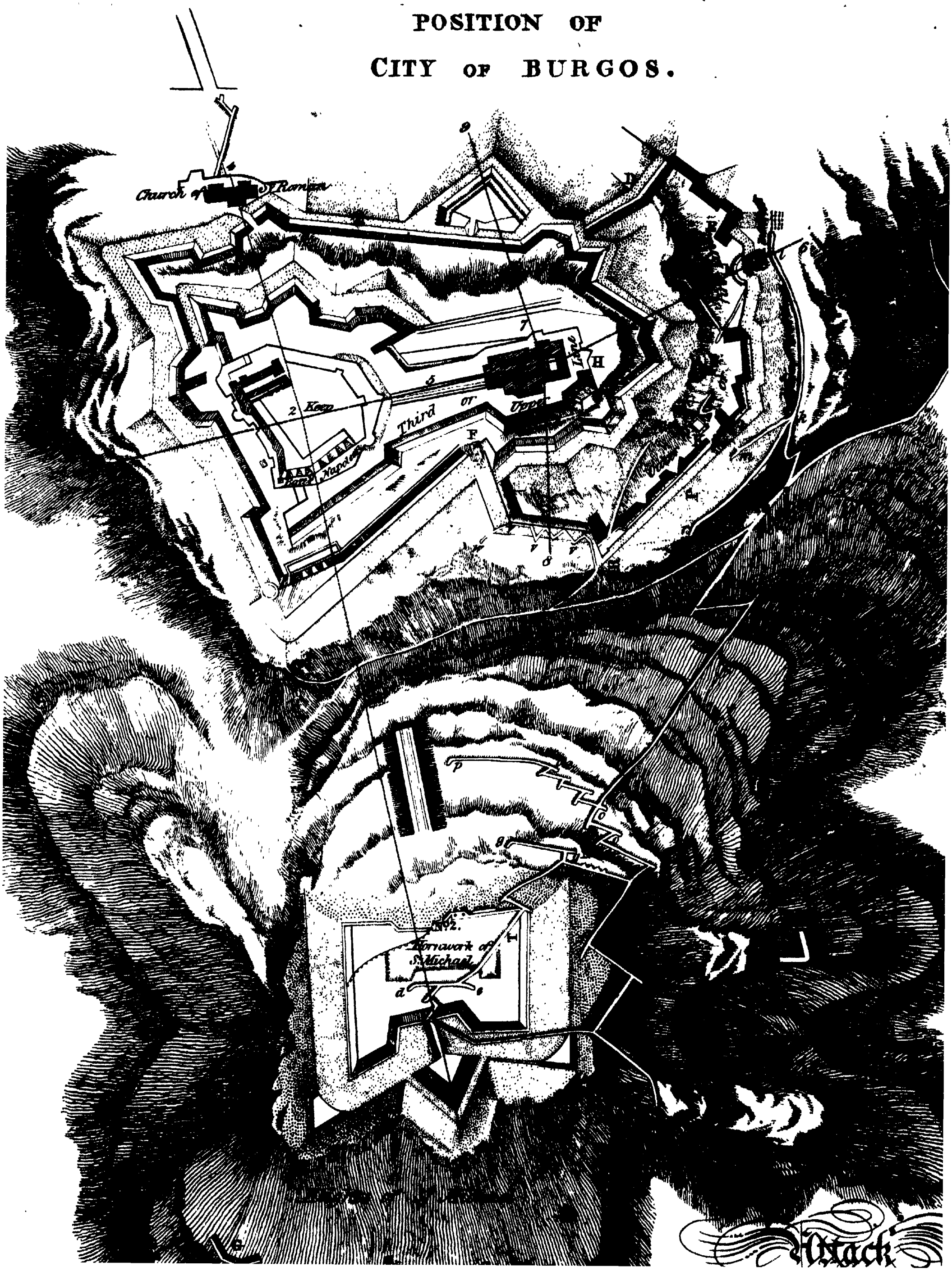
### SECOND ASSAULT.

"The storm was commenced by the Portuguese, but they were repelled by the fire of the common guard alone, and the principal escalading party, which was composed of detachments from different regiments, under Major Laurie, 79th regiment, though acting with more courage, had as little success. The ladders were indeed placed, and the troops entered the ditch, yet altogether and confusedly. Laurie was killed, and the bravest soldiers who first mounted the ladders were bayonetted; combustible missiles were then thrown down in great abundance, and after a quarter of an hour's resistance, the men gave way, leaving half their number behind. The wounded were brought off next day under a truce."—*Napier's History*, vol. v. p. 266.

The 400 men for this assault, formed of detachments under Major Laurie, of the 79th regiment, were drawn up in line, facing the hornwork, and parallel to its branches, about 300 yards from the wall of the castle to be stormed, and not in the hollow indicated in both histories just quoted. The ladders were on the right (therefore next the castle); the detachment of guards were next the ladders, and the firing party on the left, the flank furthest from the castle.

From this spot they were marched off by Major Laurie, who formed four deep, facing the whole to the right. In this order they advanced to the attack, the party with the ladders leading. It was a very clear moonlight night, and the first shot was fired by the garrison, when the party was about 200 yards off. The whole lower line took up the fire immediately; and though there were evidently not many men occupying it, the fire was well directed. The head did not hurry; and yet, by the moonlight, the column appeared to have very much lengthened out by the time the ladders reached the hollow road, which

# POSITION OF
# CITY OF BURGOS.



had been ordered as the place of formation, and within fifty or sixty yards, or less, of the enemy's wall. As the party carrying the ladders dipped into this hollow to cross it, those some distance behind them, seeing that it was a place which afforded cover, hastened to gain it; and that they might reach it the sooner, they made a half turn to the right and ran to get into it; and before the head reached the counter-scarp, the centre and rear were plainly seen spontaneously making this oblique formation, which, if they were thinking about such a matter, placed their rear rank in front, a proof that it was without command. The centre was hurrying; but the rear were running, as if not to lose their connexion with those before them; yet they were sweeping off in the direction of the suburb of San Pedro, to which, it is supposed, they ran direct. This was the firing party which was to keep the enemy off the wall. It was a great trial for the head of the column to brave the fire from the wall, and to continue to advance, whilst they could see apparently two-thirds of the whole party going off in another direction. When the ladders were on the counter-scarp, and within about thirty or forty feet of the enemy's muskets, the party carrying them hesitated for a moment. The ladders were almost turned sidewise to the ditch, as if the bearers were wavering whether they should go forward or return. Up to this moment they had marched in silence: a cheer at the instant of wavering determined them to enter the ditch. The foot-guards, which were next, all followed; and one third of the party, or perhaps some more, entered the ditch. But confusion was necessarily the consequence of detachments of different corps unknown to each other being all mixed; and there being no firing party at the spot ordered, the men in the ditch were obliged to fire up at the defenders, to save their own lives.

Nor were the ladders planted with little opposition, as has been supposed; for one long ladder, of about thirty-four feet long, was twice thrown down, and three times reared. Its top projecting above the parapet, allowed the defenders to lay hold of it. They boldly stood upon the top of the parapet, and as many French muskets with bayonets as could reach it, were thrusting to overturn it; and all the English bayonets and serjeants' halberds at the bottom, that could get at it, resisting them; whilst others on both sides were loading and firing at those disputing round this ladder. It was a singular contest, and maintained for a considerable time. Twice by such efforts did the French succeed in throwing this ladder down, and a third time the assailants reared it. It was then that the defenders threw four-pounder cannon-balls on the assailants' heads; and it was said at the time, in the ditch, that Major Laurie had been killed by one of these. Soon afterwards, coils of common artillery slow-match, lighted all over, were thrown amongst the assailants, and this caused much more confusion than at first might be supposed; for the men's pouches being all open, and they engaged in taking out cartridges and loading, a great many pouches blew up. The efforts of many of the officers were heroic, and they fell wounded from top to bottom of the ladders.

The drawing off the remnant of this party is well described by Sir John Jones. The men retired by a regular word of command from the senior officer alive; and at the foot of the glacis, the Honourable Lieutenant-Colonel Gordon, aid-de-camp, was met by them, conveying Lord Wellington's orders for their retreat.

The reason why the troops assembled where they did, and marched direct to the assault from that spot, instead of the hollow road indicated in the orders, within fifty or sixty yards of the wall (and where the historians believe they did actually assemble,) may have been because nobody, in so clear a moonlight night, could have reached that hollow road without being discovered: but had the commanding officer formed a larger front, and marched in compacter order, he would, notwithstanding, have carried the whole into this hollow way, and the attempt would at least have been made as intended.

The third assault on the castle of Burgos, is a striking instance of the disadvantage of night attacks. Though close to the breach, the storming party, with the exception of five individuals, went to the wrong place on the springing of a mine, and did not find the breach made by it. But the next assault, the fourth, was so well arranged and executed, that it may be taken as a model for such operations. Instead of mixed detachments from different corps being taken, one entire battalion, the second battalion of the 24th regiment, was ordered for this duty, and Lieutenant-Colonel Jones, of the Royal Engineers, was sent by the Earl of Wellington to post them. The arrangement made for it, as well as the execution of that assault, are well described in his own work, the 'Journal of the Sieges.' New confidence seemed infused into the troops by the judicious dispositions. We must refer those who would read it to the 'Journal.' It was conducted in strict conformity to the principle stated in the second and third paragraph of this article. A wing of the battalion was posted opposite each breach in close column of companies, as nearly as they could so form, and under cover, very close to the enemy. It was in daylight. There was a proper firing party well posted. When the mine sprung opposite the right wing of the battalion, which was to open a breach for its entrance, throwing up the earth, as usual, to a great height in the air, this half battalion did not even wait for its fall, but marched forward amidst the falling clumps, and in a few moments were in possession of the breach. The left wing moved forward as gallantly as the right, opening, as they ascended the slope, from close column to about column of quarter distance, and entered the breach in a compact irresistible body. On the alarm, the defenders rose from behind a retired parapet which they had formed in rear of the breach they were to defend. Their front rank appeared to be armed with spears, one of which Lieutenant Frazer, the brave leader of this wing, was seen to wrest from an opponent, and then to leap into the midst of the enemy, instantly followed by all his men. The names of Hedderwick, who commanded the battalion, and of Frazer and Holmes, who led the wings, have been deservedly recorded in the histories of the operation.

The details of the fifth and last assault on the castle of Burgos, are very well described in the 'Journal of Sieges,' and we can add but little to what is there stated. This assault was in daylight, and bravely executed by all engaged; yet though successful to a certain extent, the place was not carried. The ancient keep, which we believe was between forty and fifty feet high, together with the fortified church of La Blanca, gave the garrison two secure points of support on the highest ground of all: and these secured points on the summit, with the many lines, one below the other, running round the castle hill, enabled the French governor to attack the flanks as well as front of the assailants, who were comparatively in much smaller numbers than the besieged, said to have been at the beginning between 2000 and 3000 men.

It was said, during the siege, that our great commander advocated the system of assaults in small numbers, and by successive bodies, in the manner detailed in his orders for the different assaults of Burgos; that by exposing but a few men at a time, the chance of casualties in killed and wounded was proportionally diminished; and that if small numbers did their duty, they would succeed as well as large. Few, if any of the officers, however, were of the same opinion, for the impression made upon the men by sending small numbers was known to them. For example: before the party for the assault of fort Gaytano, at Salamanca, which failed, marched off, and they were "standing at ease," there was a general conversation amongst the soldiers, on the impossibility of success with such small numbers as they were. Those who wish to consider the subject of assaults, will do well to read Note 25, at the end of the '*Journal of Sieges in the Peninsula*,' where they will find this part of the subject discussed.

The numbers who actually attacked at the principal point in this last assault, appear to have been only about 400 men. Two hundred men of the Guards who attacked the second line, on carrying it, had ranged themselves on its berm. It was an indented line, and when the besieged reserves were brought forward, and they re-occupied their banquette, their fire, being exactly an enfilading one, had a most destructive effect on the Guards, who still for a while continued to maintain their place, until apparently half their numbers had fallen into the ditch, killed or wounded. To those who were looking on, it was a striking practical example of the effect of flank-fire in fortifications; and perhaps there could not have been a stronger instance of the defect of the want of it, than in the second assault on the lower line. Whether, if a number superior to the whole garrison had been sent to this assault, the place would have been taken, we shall leave to the judgment of our readers; and if we shall have induced reflection on the subject of assaults, our chief object will have been obtained.

One point more only we shall at present advert to; viz. that system, deeply rooted in the British army, of doing duty by detachments. Learnt in the garrisons and quarters at home, it is carried into the field before the enemy, and the fundamental organization by companies and battalions is set aside, in some of the most important operations, and new bodies formed at the moment of as many different corps as it is possible to collect. Whether it be for an ordinary guard, for an assault, for a working party in the field, or for any other duty, no one who reflects upon the subject will for a moment doubt the advantage of leaving troops as organized, with their proper officers and non-commissioned officers, and leaving together the men who are acquainted with each other. The only point in which there may be a difference of opinion, is in the degree of value or loss, by preserving bodies entire, or breaking them up, to remodel them for every duty. There may be operations in which a company of fifty men would be worth as many as 100 of detachments, or a battalion of 500 worth more than double this number collected in small numbers from various corps.

This principle is akin to one which did prevail in war in the British army, and may again, by first injuring eight companies of each battalion, to form two of elîte, and then injuring the battalions themselves, by taking these two elîte companies from them to form corps apart.

W. REID,
*Lieutenant-Colonel, Royal Engineers.*

## II.—*Account of the Attack of Fort Laredo near Santoña.*

During the Peninsular war, the French occupied and fortified almost all the sea-ports along the northern coast of Spain, in order to prevent, if possible, the introduction of arms and warlike stores by the British navy, who were actively employed supplying the Spanish guerillas; and one of the most important points, as well as one of the strongest by nature, was Santona.

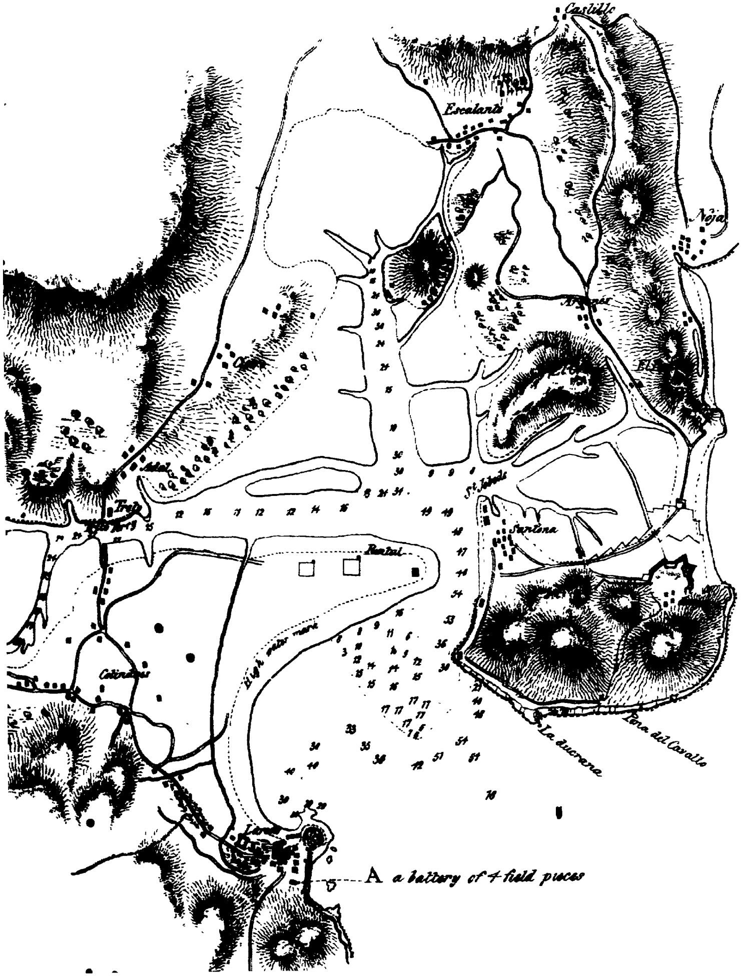
It owes its strength to one of those remarkable peninsular heights, so common on the coast of Spain; and which, like Gibraltar and San Sebastian, are so frequently connected with the main land, by low isthmuses, forming bays fit for the anchorage of shipping.

Besides fortifying the peninsular hill of Santona, the French, in order to secure the anchorage for themselves, constructed detached forts beyond the isthumus and round the bay, viz. two covering the isthmus, called el Gromo and el Brusco; and other two, el Puntal and Laredo, on the opposite side of the bay. Laredo is a commercial town of considerable importance, at the entrance of the bay, and opposite the peninsular hill of Santona. Its position and that of the other forts will be found on the general plan.

The garrison occupied the town of Laredo; but the defence of this part depended chiefly upon the fort constructed at the further end of a small peninsula, surrounded by a steep cliff.

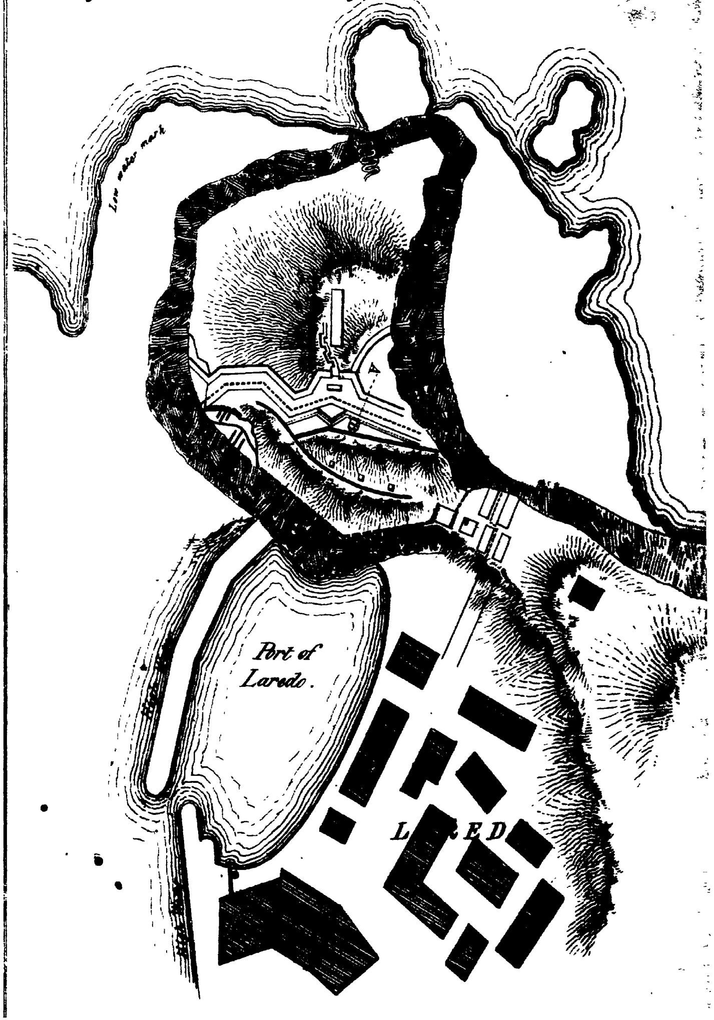
From the fort the ground gradually descended towards the isthmus, which was about sixteen feet high at the lowest part, and this isthmus narrowed until the whole breadth was occupied by a house, which was also fortified. The annexed plan and section of Fort Laredo show the nature of the fortifications, which were flanked, palisaded, and fraised. That part of the cliff within the fort was inaccessible to escalade, but the rest of the cliff, from the fort to the fortified house on the isthmus, although scarped, was found to be accessible.

The harbour thus secured, the French government sent a corvette and other armed vessels there, to cruise on that part of the coast; and they not only succeeded in interrupting the coasting-trade of the country, but took several




A a battery of 4 field pieces

during the night of the 23rd & the day of the 24th Feb.y 1814.



English vessels laden with stores for the British army, which at that time was near Bayonne. These ships had to make the port of Passages at the bottom of the bay of Biscay; but owing to a current which sets round the bay, and on the Spanish coast runs from east to west, vessels generally find, on making the land, that they are to the westward of their supposed course, which gave an additional chance of success to the cruisers in Santona.

To put a stop to the French cruising, the Duke of Wellington (who at this period commanded the three allied armies,) sent instructions to the Spanish general commanding the blockade of Santona to confine the enemy within the peninsula.

The reports upon the execution of these orders are given in the translations of the following dispatches, published in the Spanish official gazette of the Regency, dated 23rd of March, 1814, from which we have extracted all that is interesting; and we prefix to them the Duke of Wellington's to the Secretary at War, when he forwarded those of the Spanish officers to their own government.

The following is the dispatch of the Duke of Wellington, addressed to the Minister at War:—

"Sir,

"The towns in the immediate vicinity of Santona, as well as the coast-trade of the north of Spain, having suffered from the shelter which the port of that place afforded to the enemy's cruisers, who could come out with impunity, I determined to confine them, as far as I should be able, by shutting them up within the fortifications of the peninsula; for which purpose I caused the blockading force to be augmented by a brigade from the fourth army, and placed the whole of it under the command of Brigadier Don Diego del Barco, giving him his instructions; and who has completely fulfilled his commission, as your Excellency will see in the accompanying report which I have just received from Don Manuel Freyre, general in chief of the fourth army, as well as another, which I inclose, and which relates to the assault made on the fort of Puntal. At the same time that I have the satisfaction to make known to you the successful services of this gallant commander, I regret to say that he has fallen, though honourably, in executing his duty, as your Excellency will see by a copy of the report of Colonel Llorente. The qualities which adorned the Brigadier Barco, are so well known, in addition to the important service just rendered to his country, and as he cannot now receive the rewards which he would have so well deserved, had he survived, I trust the Regency will be pleased to confer the reward they would have bestowed on him, on some one of his family, who may be in his country's service.

"I request your Excellency, in laying before their Highnesses the details of these operations, which have deprived the country of the further services of this chief, to place before them the merits of the commanding officers, and officers who have distinguished themselves in their execution.

"I have the honor, &c.

(Signed) "WELLINGTON, *Duke of Ciudad Rodrigo*."

Translation of the report of Brigadier Barco, to General Freyre, giving an account of the fort of Puntal.

"*Most Excellent Sir,*

"Observing that the enemy were working with the greatest activity at the fort of Puntal; believing that a coup-de-main would give me possession of it, cutting short the enemy's projected improvement of his defences, and if I could hold it, preventing his using it against my ulterior operations; I determined to escalade this fort on the night between the 12th and 13th instant, although earlier than I designed to have attacked it; which operation I entrusted to Colonel Don José Miranda, of the regiment of Monterey: accordingly the fort of Puntal was carried by assault, with the greatest order and bravery, by the light infantry company of that regiment, commanded by Captain Don Antonio Nicolao.

"After the fort was taken, the enemy shut themselves up in the guard-room, and there resisted determinedly, but the door was burst open, and an officer and twenty-three men taken prisoners, and thirty bayonetted. The capture of the guard-room was facilitated by the bravery of a soldier, who having carried an axe to the assault, got upon the roof, and making an opening in it, threw the tiles upon the defenders.

"The capture of the fort confirmed the opinion I had of the great quantity of cannon which protected it from the other side at Santona,* which made me determine to destroy the work: and in the night we cut the fraises, and spiked two 24-pounders, and broke up their carriages, as we could not remove them. At dawn of day we left only a picket of observation in the fort, supporting it at a proper distance. At daylight the enemy opened a heavy fire of cannon upon

* This redoubt of Puntal was protected by sixty pieces of cannon from Santona.

the fort and its vicinity, which after a time they suspended. In the interval, the regiment of Monterey was relieved by that of the volunteers of Leon. At ten o'clock the enemy recommenced their fire; but as this had no effect in dislodging the troops from the fort, the garrison placed 600 men in boats, and under the protection of more than fifty pieces of cannon, prepared to pass over, upon which the Colonel commanding the volunteers of Leon drew off his parties in good order. The enemy, however, remained under the protection of their own guns.

"At night the posts were re-established as before, in which operation we had the misfortune to lose the Lieutenant Don Eusebio Rodriguez, killed, whose loss is much lamented by his Colonel and brother officers; and Captain Wells, of the British Engineers, whose professional knowledge and acquaintance with the ground has been of much use to me, received a contusion."

The remainder of this dispatch is taken up in the recommendation of officers.

Translation of a dispatch from Colonel Don Juan José Llorente, who succeeded to the command of the blockading force, on the death of Brigadier Barco, and which details the remainder of the operations ordered by the Duke of Wellington. The dispatch is addressed to General Freyre.

"Most Excellent Sir,

"In my report of the 23rd instant, which I sent by the common post, I gave you an account of the first operations which had been executed against the outworks of Santona and the fort of Laredo. I have to-day the satisfaction to make you acquainted with the happy termination of these operations; and in case my other report should have been delayed, I shall repeat these details to your Excellency, which are as follows.

"On the arrival of the proper commandant of the blockading force, Don Diego del Barco, I was destined to command on the left with my own brigade, and the recruits of the quartos 2d and 3d Biscayan regiments. On the 21st, Brigadier Barco gave his orders and instructions for the assault of fort Laredo, and I was desired at the same time to attack the two works of el Brusco. Every preparation being made in the course of the day, the attack and escalade of the town and fort of Laredo, were commenced at nine o'clock at night, by the regiment of Toledo, the volunteers of Leon, and the light infantry company of the regiment of Brueba, and the grenadiers of Monterey. These corps were commanded in person by the Commandant-general. The valour and devotion of the troops, officers, and chiefs, in executing this service, was admirable. They quickly entered the town and outer intrenchments of the fort, taking one piece of artillery, some prisoners, and probably would have got possession of the principal post, if their progress had not been checked by a mortal wound received by the Commandant-general at that decisive moment; depriving the troops of the necessary instructions. Notwithstanding this misfortune, and the obstinate defence of the enemy, the troops maintained themselves at the foot of the glacis, and dispositions were made to keep what had been gained with so much bloodshed: accordingly they maintained these points in spite of the fire of artillery, musketry, and other projectiles.

"On the morning of the 22nd, I attacked the first work of el Brusco, and carried it without firing a shot; but its garrison were enabled to escape by a rocky path which led down to the beach. I then caused the other and principal work of el Brusco to be attacked, which was on the most inaccessible height of these mountains, and immediately in front of Santona.

"The garrison of Santona made great efforts, in two sallies, to dislodge us from a position I occupied after the first attack, and which invested and cut off the principal work of el Brusco; but they were driven back, and abandoned this other fort to its own defence, after suffering a considerable loss. Then the troops having got nearer to it, found it inaccessible; and satisfied that it was so, as well as being convinced that the garrison could not support it, I determined to maintain my position, and closely to invest this work, as it would in time be obliged to surrender for want of provisions. This operation, and the occupation of the village of Argonas, narrowed the blockade at this part.

"At four in the afternoon of this day, I received intelligence of the severe wound of Brigadier Barco, and also his orders to me, as next in command, that I should continue the operations against Laredo, as being the most important. In consequence, I arrived next day at Laredo, examined the defences of its fort, and resolved to commence trenches against it in the night, maintaining in the mean time the difficult and exposed positions of the flank companies of the regiment of Leon, on the glacis; convinced that if this could be maintained, the approaches would be shortened, and quicker pushed forward.

"The courage and constancy of the troops facilitated the result so earnestly desired; for during the night, the companies of miners, and the first of the sixth battalion of the sappers, under the direction of Captain Wells, of the British Engineers, having by the flying sap established two branches of approach or parallels, which were indispensable to arrive at the palisaded covered-way, enabled us to cover our troops in trenches, and to silence, by a superior musketry fire, both the musketry and artillery of the enemy; their men being shot on every attempt to reload their cannon. The works were proceeded with on the 24th, notwithstanding that the enemy threw into them projectiles of various descriptions. At sunset we were crowning the glacis, and marking out passages in the ditch, and a breaching battery to receive the only guns we had.

" From the rapid progress of the works, and the well-directed musketry fire, the enemy fully expected they might be attacked by assault before morning. At nightfall, they therefore proposed to capitulate: which I admitted; granting them only the honours of war; the fort to be given up within an hour, or else hostilities to recommence; but after a short interval they surrendered the fort, and our troops took possession of it at nine at night.

" Nine officers, 256 non-commissioned officers and soldiers, ten pieces of artillery, from eight-pounders to thirty-six-pounders, has been the result of this rapid operation, and the command of the entrance of the harbour of Santona, which is known to be so important.

" The loss of the assailants has been,

" Killed—One officer, two serjeants, and thirty-four privates.

" Wounded—Four officers, six serjeants, and eighty-four privates.

" Contusions—Eighteen privates."

The remainder of the dispatch, signed by Colonel Llorente, is chiefly taken up with the names of officers and regiments who distinguished themselves, or were employed during the attacks.

On the following day, Colonel Llorente reported, that the enemy had drawn off the garrison which they left in the principal work of el Brusco, protecting their retreat by a vigorous sally; and he adds, that he has no doubt but that the rapid progress of the attack on Laredo, caused the enemy to abandon these works in front of the isthmus.

The fort of el Brusco was a building of masonry, loopholed, and with machicoulis, with a garrison of fifty or sixty men.

El Gromo was an irregular crownwork, containing several guns, and a garrison of 400 or 500 men.

The plan and section of Laredo will sufficiently explain the nature of that work.

On the night of the 22nd of February, 1814, the Spanish engineers erected a battery (at the point marked A in the general plan of Santona) of four eight-pounders, which were the only guns in possession of the Spanish troops. This battery was about 600 yards from the fort of Laredo, and scarcely a shot was fired from it before the battery was disabled by the fire from the fort.

This result had been predicted by Captain Wells, who executed the plan of attack which he himself had advised; viz. under a protecting fire of musketry,* to push forward trenches of attack to the covered-way, and to place what guns they had there, in order to burst open the gate and cut the palisades.

To prevent the enemy from hearing the noise of the pickaxes and shovels, a half company were stationed on the left, and relieved every hour, with orders to keep up a continued fire on the enemy's parapet. The night was very dark; and although they threw many light balls, and fired grape-shot occasionally, there were not more than six sappers and miners killed or wounded during the night; the enemy were in fact in ignorance of the work that was going on. The first portion of the trench executed was that nearest the enemy, along the edge of the covered-way.

When the garrison surrendered, it was ascertained that their muskets had become so foul, that a great many would not go off. They had been so constantly kept on duty on the ramparts, that they could not clean them.

(Signed) W. REID,
Lieutenant-Colonel, Royal Engineers.

* The revival of the use of wall-pieces, and the improvement in their construction, will give additional force to this mode of attack. Wall-pieces are said to have been used in great numbers by the French during their siege of Algiers. These pieces had a swivel, and were made to load at the breech, but they were awkwardly long.

## III.—*Notes on Concrete. By Lieutenant* Denison, *Royal Engineers.*

The very general employment of the mixture of lime and gravel, commonly known by the name of concrete, in all foundations where, from the nature of the soil, precautions against partial settlements appear necessary; and the great probability of an extension of its use, in situations where the materials of which it is composed are easily and cheaply procured, must of course render it a subject of great interest to the engineer.

The paper which conveys most information on this subject, is a prize essay by Mr. G. Godwin, published in the 'Transactions of the Institute of British Architects.' In this essay, many instances are brought forward of the employment by the ancients, of a mixture analogous to concrete, both for foundations and for walls. Several cases are also mentioned in which, of late years, it has been used advantageously for foundations, by some of the most distinguished architects and civil engineers. In these latter instances, the proportion of the ingredients vary from one of lime and two of gravel, to one of lime and twelve of gravel; the lime being in most cases Dorking lime, and the gravel Thames ballast.* The proportion, however, most commonly used now, in and about London, is one of lime to seven of ballast, though, from experiments made at the building of the Westminster new Bridewell, it would appear that one of lime to eight of ballast made the most perfect concretion.

Concrete, compounded solely of lime and screened stones, will never assume a consistence at all equal to that of which sand forms a part. The north wing of Buckingham Palace affords an instance of this. It was first erected on a mass of concrete composed of lime and stones, and when subsequent alterations made it necessary to take down the building, and remove the foundation, this was found not to have concreted into a mass.

* It is a question for consideration, whether a great variety of sizes in the materials used, would not form the most solid as well as the hardest wall. The walls of the fortress of Ciudad Rodrigo, in Spain, are of concrete. The marks of the boards, which retained the semifluid matter in their construction, are every where perfectly visible; and besides sand and gravel there are every where large quantities of round bolder stones in the wall, from four to six inches in diameter, procured from the ground around the city, which is every where covered with them.—*Lieutenant-Colonel Reid, Royal Engineers.*

Mr. Godwin states, as the result of several experiments, that two parts of stones and one of sand, with sufficient lime (dependant upon the quality of the material) to make good mortar with the latter, formed the best concrete. As the quality of the concrete depends therefore on the goodness of the mortar composed of the lime and sand, and as this must vary with the quality of the lime, no fixed proportions can of course be laid down which will suit every case. The proportions must be determined by experiment, but in no case should the quantity of sand be less than double that of the lime. The best mode of compounding the concrete, is to thoroughly mix the lime, previously ground, with the ballast in a dry state; sufficient water being then thrown over it to effect a perfect mixture, it should be turned over at least twice with shovels, and then wheeled away instantly for use. In some cases, where a great quantity of concrete has to be used, it has been found advisable to employ a pug-mill to mix the ingredients: in every case it should be used hot.*

With regard to the quantity of water that should be employed in forming concrete, there is some difference of opinion: but as it is usually desirable that the mass should set as rapidly as possible, it is not advisable to use more water than is necessary to bring about a perfect mixture of the ingredients. A great change of bulk takes place in the ingredients of concrete when mixed together. A cubic yard of ballast, with the due proportion of lime and water, will not make a cubic yard of concrete. Mr. Godwin, from several experiments made with Thames ballast, concludes that the diminution is about one-fifth. To form a cubical yard therefore of concrete, the proportion of lime being one-eighth of the quantity of ballast, it requires about thirty cubic feet of ballast, and three and three-quarters cubic feet of ground lime, with sufficient water to effect the admixture.

An expansion takes place in the concrete during the slaking of the lime, of which an important use has been made in the underpinning of walls. The amount of this expansion has been found to amount to about three-eighths of an inch to every foot in height, and the size thus gained, the concrete never loses.

* Mr. Godwin states, that the setting of ordinary lime results from the absorption of carbonic acid gas from the atmosphere. That the limes of mortars become sooner or later carbonates, is most certain, but there is no proof that this is the cause of their cohesion; indeed there is every reason to doubt it. It is more probable that new attractive properties are acquired at the moment that hydrates of lime are formed from calcined lime and water, when in close union with silex, alumina, and some other substances, and that the properties first acquired at that time, do not cease immediately, but continue, if undisturbed, for ages.—*Lieutenant-Colonel Reid.*

The examples from which the above rules are deduced, are principally of buildings erected in or about London; the lime used is chiefly from Dorking, and the ballast from the Thames. It is very desirable that a more extended collection of facts should be made, that the proportions of the materials, when other limes and gravels are used, should be stated, in order that some certain rules may be laid down by which the employment of concrete may be regulated under the various circumstances which continually present themselves in practice.

The Dorking and Halling limes are slightly hydraulic. Will common limes, such as chalk and common stone-lime, answer for forming foundations of concrete, where the soil, although damp, is not exposed to running water? Is it possible, even with hydraulic lime, to form a mass of concrete in running water?* If common lime will not answer, may it not be made efficient by a slight mixture of cement? These, and questions similar to these, are of great interest; and facts which elucidate them will be valuable contributions to the stock of knowledge on this subject.

(Signed) W. DENISON,
Lieutenant, Royal Engineers.

* As all *limes* are soluble, more or less, in fresh water, this seems very doubtful. Any attempt to check a spring, or stop the course of running water with fresh concrete, will certainly fail. An instance of this was seen at Chatham, where Mr. Ranger was constructing a dock with his patent concrete: in the floor of the dock were several springs, which, in spite of every attempt to check them with concrete, continually made their way to the surface, and in every case it was found that the lime had been washed away from the mass, leaving only the gravel and sand behind. Eventually it was found necessary to carry away the water in an iron pipe, and discharge it into the drain outside the dock. Mr. Godwin states, that the dock at Woolwich failed from using separate moulded masses of concrete, instead of employing it as one whole. In this case, had separate masses been used, and laid in cement, the work might have been carried on, though it might perhaps have failed eventually, from the solubility of the lime in fresh water affecting the blocks.—W. D.

IV.—*Description of the Method adopted by Mr. Taylor, for Underpinning with Concrete, the Storehouses in Chatham Dock-yard. By Lieutenant* DENISON, *Royal Engineers.*

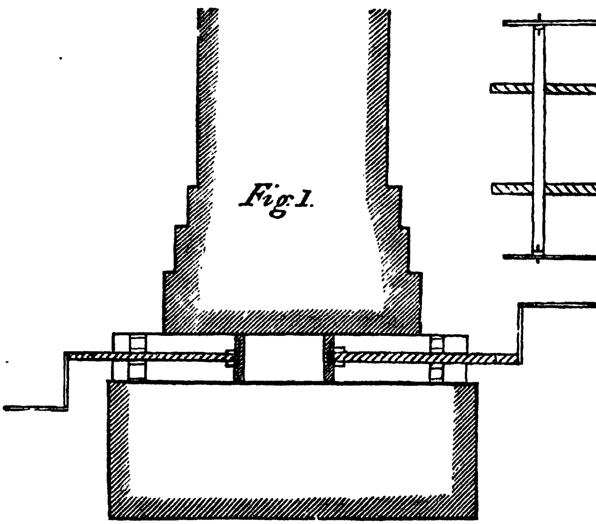
ONE of the large storehouses in Chatham dock-yard, having for some time exhibited serious defects in its walls, the attention of the Admiralty was directed to it in the year 1834, and Mr. Taylor, the civil engineer and architect, was directed to report upon the best mode of obviating the evil.

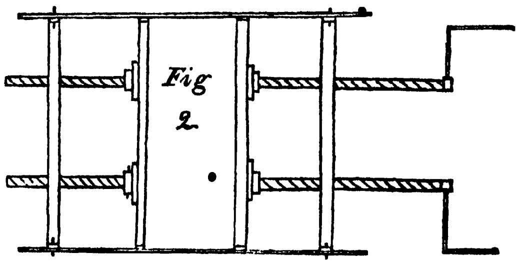
Upon investigation, the foundation of the storehouse (a building 540 feet in length, and 50 in breadth,) was found to be in a very bad state; the front wall, nearest the river, had originally been built upon piles, while the rear wall was laid upon an upper stratum of five or six inch plank, supported by two rows of transverse and longitudinal oak sleepers lying on the surface of the ground, which in this case was of a variable consistence, containing flints bedded in a sort of clay, quite pervious to the water, which at high tide rose some height upon the foundation. The sleepers, and heads of the piles at the front of the building, thus exposed to alternate moisture and dryness, were in a state of rapid decay; in some places they were even reduced to a powder; and it was possible for a man to move under the walls in the space previously occupied by the timber: in the rear, the case was pretty much the same; the sleepers were universally in a state of decay, but in some places were much further advanced towards decomposition than in others.

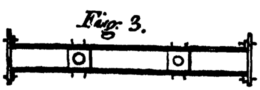
The state of the storehouse requiring immediate attention, it was resolved to attempt to underpin the walls; and this Mr. Ranger, the patentee for the new description of concrete, or artificial stone, undertook to do, he having adopted a plan proposed by Mr. Taylor, for forcing the soft concrete against the under part of the wall; and he proceeded to execute his contract in the following manner.

I must premise, that the storehouse was vaulted underneath, and that the piers, or cross walls, required as much underpinning as any other part of the building.

The walls were laid open to their bottom, both inside and outside the building; in the front, the heads of the piles and the sleepers were removed for a depth of about four feet below the bottom of the wall, and for lengths of about five feet at one time. In the rear, all the planks and sleepers were removed for the same distance. A mass of concrete, composed of one-eighth of Halling lime (reduced to a powder by grinding, and in a perfectly caustic state,) and seven-eighths of Thames ballast, mixed up with so much boiling water as to reduce the whole to a pasty consistence, was then thrown from a height of about fifteen feet underneath the wall: it was allowed to project about a foot on each side, where it was confined by planks, and after being roughly levelled, it was well rammed, to give it as much consistence as possible. This mass was raised about three feet, or to within one foot of the bottom of the wall; it was then carefully levelled, and covered with half-inch slates. A kind of framework was then placed on the slates, consisting of two cross-plates of iron, placed perpendicularly to the direction of the wall, about one foot wide, and long enough to project about one foot on each side of the wall. (See wood-cuts below.)



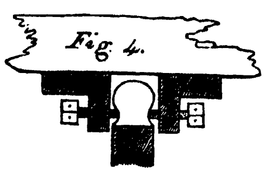




*Fig.* 1. Section of wall, framework, and concrete foundation.

*Fig.* 2. Plan of framework.

*Fig.* 3. Elevation of cross frame and sockets for screws.

*Fig.* 4. Mode of fastening head of screw to board.

To these were fixed two frames parallel to the wall, about four feet long, each carrying two sockets for screws. Within these frames were placed two moveable planks, long enough to pass just free between the cross-plates, and wide enough to fit nearly the space between the slates and the bottom of the wall. Upon these planks were sockets for the heads of the two screws, by which the planks were pushed forward, or withdrawn at pleasure.

When the apparatus was fixed, and the moveable planks ready on both sides of the wall, about two barrows-full of concrete, mixed as above, were thrown in from above; the workmen below then commenced turning the screws on each side simultaneously, moving the two planks towards the centre of the wall, and forcing the concrete before them into all the vacant spaces, and against the bottom of the wall. When the plank was forced forward as far as it would go, by the force of two men to each screw, the concrete was allowed to rest for about five or ten minutes, by which time it had set hard enough to stand by itself, and its expansion in the act of setting completed what the pressure of the screws might have left undone. The planks were then withdrawn, another charge thrown in on each side, and compressed as before, and this was continued till the whole space between the frames was filled with concrete. The screws were then removed, the boards and frames unbolted and taken out, and lastly, the side-plates were withdrawn, leaving an interval of about three quarters of an inch between each mass of concrete, which space was afterwards filled in with grout.

The above description is given from notes taken at the time. Mr. Taylor has since published an account of the same work in the 'Transactions of the Architectural Society,' which does not differ materially from the above. The proportion of lime to gravel, he there states as one to six; and he brings forward more prominently the difficulties which were encountered, and the efficiency of the concrete in the mode in which it was applied. No settlement has taken place since the work was completed.

(Signed) W. DENISON,

Lieutenant, Royal Engineers.

## V.—*Description of a Concrete Bomb-Proof erected at Woolwich, with Detailed Experiments as to the Effect produced on it by the Fire of Artillery.*

Copy of a Report from Lieutenant-Colonel Harding, Commanding Engineer of the Woolwich District, to the Inspector-General of Fortifications, reporting on the Applicability of Concrete to the Formation of Arches, &c.

SIR, Woolwich, 29th June, 1834.

IN pursuance of your orders of 23rd December, 1834, to superintend the experiment of forming an arch with concrete, to be carried on by Mr. Ranger, and to report the result; I have to state, that on conferring with him, it was decided to place the arch near the practice-butt in the marshes at this place, in order that the effect of shells upon it might be ascertained.

The work was accordingly commenced by Mr. Ranger, and carried on as detailed in the annexed Report, to which are attached the drawings necessary to show the dimensions of the arch and mode of construction.

The arch was completed on the 17th March, 1835, and the centres struck on the 21st March, 1835, shortly after which a gradual settlement was observed in the piers, owing to the nature of the soil of the marshes, which is a soft spongy peat to a great depth. The foundations, as will be seen by the section, were formed of concrete, extending one foot beyond the pier: a more equal settlement might perhaps have been obtained if they had been formed in one bed or platform, which it might be advisable to do in future buildings in marshes, though at the time it was not considered necessary in an experiment on so small a scale.

The piers sunk, at irregular periods, to the depth of eleven to twelve inches, causing a small crack or fissure in the crown of the arch, showing in the whole length of the soffit an opening of about three-tenths of an inch, but not materially affecting, I think, the strengthof the arch, which otherwise stood perfectly, and answered the expectation of forming arches of this material.

With respect to the economy of using concrete instead of brick or stone, I give in the annexed Report a detailed account of the price at which it might have been constructed by us, without reference to what may be charged by Mr. Ranger, as more useful in regard to its future adoption. By this it appears, that concrete in foundations may generally be formed at one-third, and in arches and in walls at less than half the cost of brickwork.

I feel therefore able to recommend its adoption in the construction of arches, both as to strength and economy; but with regard to its use in forming the centres of piers, presuming the outside to be of brick or stone, I should be doubtful till further trials, on account of the difference of compression and expansion in the two materials.

In order to ascertain the resistance which an arch of concrete would give to projectiles, with a view to its adoption for casemates and other military works, a committee composed of Officers of the Royal Artillery and Engineers, by the Master-General's order of the 14th of April, carried on the practice detailed in the memorandum attached; and I also forward a copy of the Report of this select committee on the subject. From the conclusions come to in this Report, and from what I observed in the construction of the arch, I think I may state, that an arch formed with the thickness of four feet of this material, may be considered bomb-proof, and that it may be used with safety, and in most situations with advantage, in the construction of small magazines, casemates, &c. especially if covered with the precautions usual in a besieged place.

With respect to recommending it to be adopted for large magazines, it would be necessary, before decision, to have experiments on a larger scale, to determine how far dampness may affect the material, and whether time will give it greater hardness and consistency.

Considering, from the quickness with which concrete sets in the boxes, that it might be useful in the re-establishment of merlons under an enemy's fire, and also, from its cheapness, in the formation of parapets, counter-scarps, &c. the committee tried the effect of direct fire on the piers, the result of which is shown in the accompanying memorandum. I may observe, that the penetration of the shot into the piers, showed that the interior was still damp, and the concrete friable in the hand; from which I am inclined to think, that, in masses, it will take a great time to dry perfectly, and till then may be liable to dampness in buildings; but from the similarity of the material to that used in the old Moorish walls in Spain, it may be expected to harden in the same way, those walls now hardly showing the effect of shot upon them.

I have, &c.

(Signed) GEO. J. HARDING,

Lieutenant-Colonel, Commanding Engineer.

Major-General Sir F. W. Mulcaster, K.C.H.
&c. &c. &c.

## Report on the Method of constructing a Concrete Arch, as an Experiment, at Woolwich.

Orders were received from the Board of Ordnance, to construct at Woolwich an arch of concrete, composed according to the method and proportions adopted by the patentee, Mr. Ranger, for the formation of "patent concrete," with the view of ascertaining by experiment, the fitness of this material for arches generally, but more especially for those of casemates.

*Dimensions of the Arch.*—An arch of the dimensions laid down in the accompanying sketch, No. 1, was decided upon, and a portion of a casemate eighteen feet in length, according with that section, was commenced on the 2nd February, 1835, under the directions of Mr. Ranger.

*Site.*—In order to ascertain also, by this experiment, the efficiency of this material to resist artillery, the site selected for the arch was in front of the practice-butt in Woolwich marshes.

*Materials.*—The materials used by Mr. Ranger to form his "patent concrete," are gravel, sand, lime, and boiling water.

*Gravel and Sand.*—The gravel and sand used, were taken as dredged from the bottom of the Thames, between Blackfriars and Westminster bridges; their proportions and quality varied considerably: in the state considered fittest for the purpose, the gravel consists of round stones of very unequal size, mixed with sharp sand, in the proportion of about five parts of gravel to three of sand. Some experience and judgment is requisite in the selection of the gravel, to insure equality of substance: for instance, when the gravel is mixed with much earth, it must be washed by means of fine sieves; when it contains large stones in abundance, they are rejected; and when sand and the smaller particles of stone are over abundant, the whole is screened, so as to attain nearly the relative proportions above stated.

*Lime.*—The lime employed is the best Dorking lime, ground very fine, bolted through a fine hair sieve, or coarse canvass, and carefully secured in casks till required.

*Proportions.*—The proportions of the materials, are seven parts of gravel and sand mixed as above, one part of lime, and one part and a half of boiling fresh water. Some judgment is necessary here also, for the quantities of water and lime vary occasionally, according to the dryness and quality (as to fineness) of the gravel. The finer the gravel, the more lime is necessary, and the drier it is, the more water is required.

*Method of Mixing.*—One half of the above proportions are mixed at one time; that is to say, three buckets and a half of gravel, half a bucket of lime, and three-quarters of a bucket of boiling water. Two men are employed in mixing. The gravel is spread by them equally on a mortar-board (three feet nine inches by two feet six inches, enclosed on three sides by a board seven inches deep, and open on the remaining side.) The lime is then strewed over the gravel, and the two are intimately mixed while dry, by being turned over two or three times with shovels. The boiling water is next added, and the whole again turned over two or three times till thoroughly mixed. The average time occupied in this operation is about two minutes and a half.

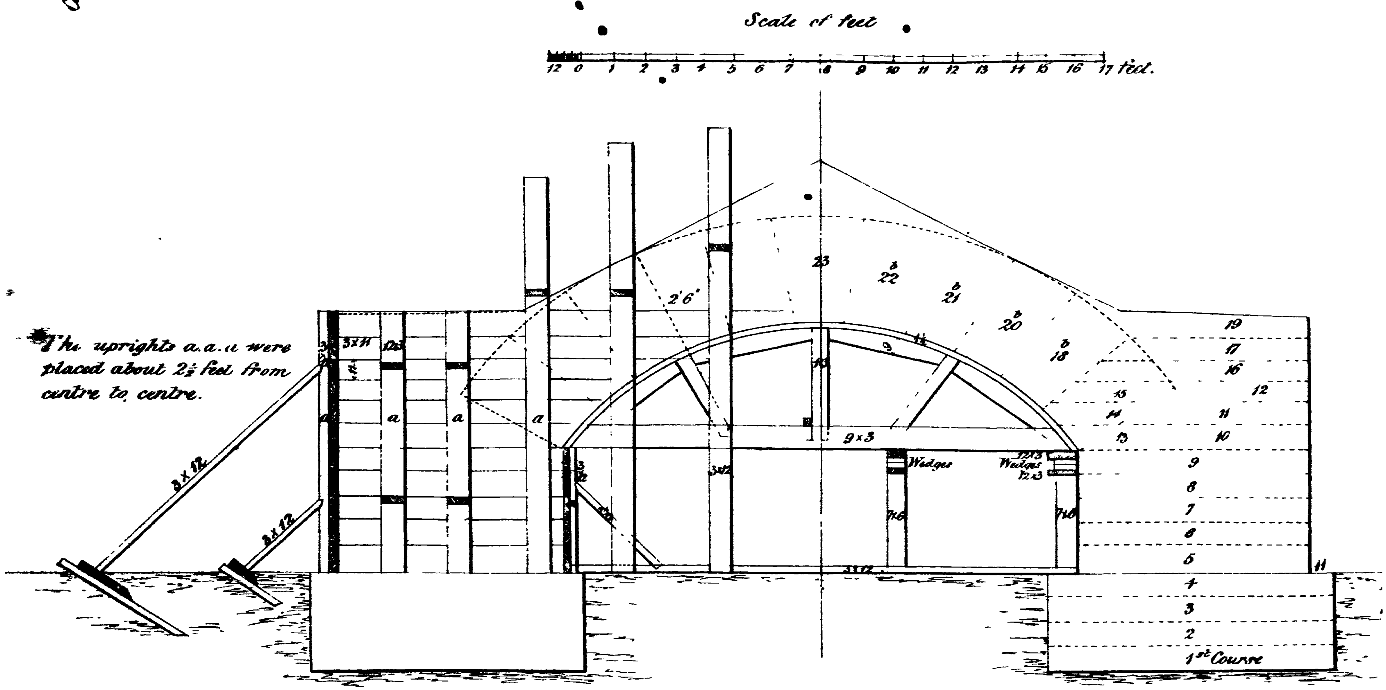
*Method of Building.*—When the concrete is thus sufficiently mixed, it is immediately dashed with shovels into the part of the building carrying on, where it is received by two men with rammers, who ram it close together, so as to secure equal consistency.

*Framework and Centering.*—This description of concrete sets with great rapidity; so fast, that a box or mould four feet long, three feet by one foot, filled with this material, turned out quite solid from the box in less than ten minutes. It expands also considerably while setting; these effects make it necessary that in building with this material, the framework, which gives the shape and dimentions of the walls and arches, should be firmly secured and braced. The manner this was effected on the present occasion, is detailed fully in the sketch, No. 1, annexed, in which is shown also the thickness and position of the courses, as they were successively built.

It is important that all the joints vertical to the courses be made square; and at the periods of leaving off work, not to commence more than will be sufficient to build to a joint by the time of leaving off.

*Expense.*—The present experiment affords but a very imperfect datum for estimating the cost of building with concrete. The situation which, for the reason already given of firing at the arch, was chosen in the marshes, at a great distance from the storehouses and the residences of the workmen, involved much additional expense; the work also was executed by a mixed party of civil labourers and convicts; six civil labourers accustomed to the work, assisted by a gang of convicts from ten to fourteen; a greater number than it would have

Sketch explanatory of the manner in which the Frame Work and Centering were secured.




NB The joints of the arch at bb &c were successively secured for the reception of the Concrete of each Voussoir. The Voussoirs (excepting the 1st) were filled in one thickness from top to bottom, but in 3 parts of the length of each, the parts being separated during the building, like the joints, by rough frame work secured to the centre and side boarding. The Nos shew the order in which the courses succeded each other; the 2 courses 22 & 23 formed the key of the arch.

been necessary to employ had they been all civilians. In order however to get at some kind of estimate of the cost of the concrete by this experiment, the number of fourteen labourers, the average necessary to be employed daily for the due execution of the work, has been taken, and calculated for the days actually occupied in the construction of the casemate; to which has been added the expenditure of materials charged at the contract prices of the Engineer Department; and the three following statements show the cost, per foot cubic, severally for the foundation, abutments, and arch, viz.

*Foundation.*

| | £ | s. | d. |
|---|---|---|---|
| 5 days' pay of an overseer, at 5*s*. per day | 1 | 5 | 0 |
| 70 ,, of 1 labourer, being 5 days' pay of 14 labourers, at per man 2*s*. 9*d*. | 9 | 12 | 6 |
| 160 bushels of lime, at 7*d*. | 4 | 13 | 4 |
| 1120 ,, of gravel, at ½*d*. | 2 | 6 | 8 |
| 9 ,, of coals, at 1*s*. 2*d*. | 0 | 10 | 6 |
| | £18 | 8 | 0 |

The solid content of the foundation equals 1440 cubic feet, which gives, at the above cost, nearly 3¼*d*. per foot.

*Abutments.*

| | £ | s. | d. |
|---|---|---|---|
| 11¼ days' pay of an overseer, at 5*s*. per day | 2 | 16 | 3 |
| 157½ " of 1 labourer, being 11¼ days' pay of 14 labourers, at per man, 2*s*. 9*d*. | 21 | 13 | 1½ |
| 296 bushels of lime, at per bushel, 7*d*. | 8 | 12 | 8 |
| 4522 ,, of gravel at ,, ½*d*. | 9 | 8 | 5 |
| 30½ ,, of coals at ,, 1*s*. 2*d*. | 1 | 15 | 7 |
| | £44 | 6 | 0½ |

The solid content of the abutments being 2325 feet cubic, gives nearly 4½*d* per foot cubic.

*Arch.*

| | £ | s. | d. |
|---|---|---|---|
| 13¾ days' pay of an overseer, at 5*s*. per day | 3 | 8 | 9 |
| 192½ „ of 1 labourer, being 13¾ days' pay of 14 labourers, at 2*s*. 9*d*. per man | 26 | 9 | 4½ |
| 354 bushels of lime, at per bushel 7*d*. | 10 | 6 | 6 |
| 3591 „ of gravel, at „ ½*d*. | 7 | 9 | 7½ |
| 30 „ of coals, at „ 1*s*. 2*d*. | 1 | 15 | 0 |
| | £49 | 9 | 3 |

The solid content of the arch with the ridge above it, equals 2182 feet cubic, which gives nearly 5¼*d*. per foot.

The above expense is exclusive of the cost of centering and framework for the support and shape of the abutments, as that expense would have to be divided amongst the cost of any work carrying on, and is not fairly chargeable to one isolated part, as the centre and frames would answer throughout, being moved from part to part, as completed in succession.

From the above account, and making allowance for additional time occupied on this occasion, and presuming that gravel can be as easily procured, it is considered that concrete in foundations may be formed at one-third of the cost of brickwork, and in arches and high walls at less than half.

The specific gravity of concrete, by the mean of three trials, was found to be 2.2035, &c., its actual weight nearly sixteen cubic feet to a ton, which is nearly that of Portland stone. This is the weight taken in the foregoing calculations, of the several weights of the parts of the experimental casemate.

(Signed) CHA. C. ALEXANDER,
Captain, Royal Engineers.

(Signed) GEO. J. HARDING,
Lieutenant-Colonel, Commanding Engineer.

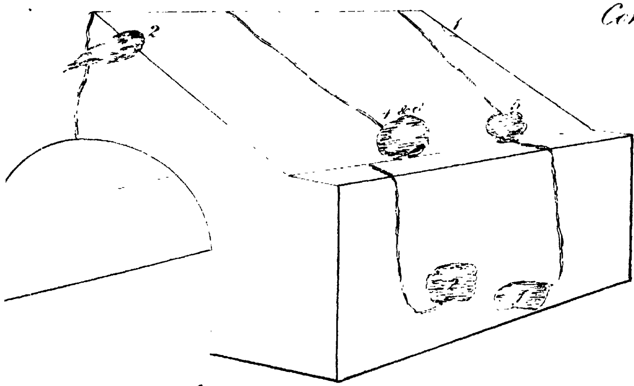
Memorandum of the Effect produced by the Fire of Artillery, on the Concrete Experimental Casemate, in Woolwich Marshes, in the Month of May, 1835.

Woolwich, June 6, 1835.

The mortar practice was from two thirteen-inch mortars, at the distance of 500 yards. The shells were filled with sand, and plugged, to the weight of

Concrete Bomb Proof. Pl. 2

Fig. 1.



Three Sketches shewing the several positions in which the Concrete Experimental Casemate was struck by Shells & Shots during the practice carried on in Woolwich Marshes May 1835.

Fig. 2.

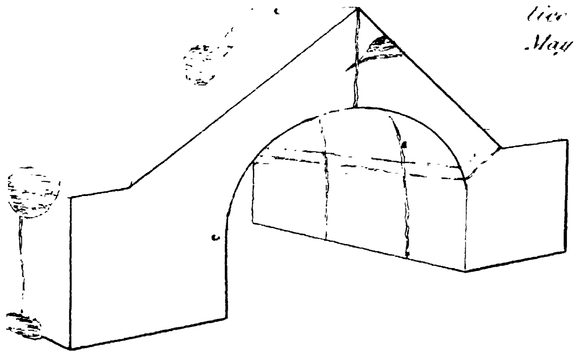


Fig. 3.

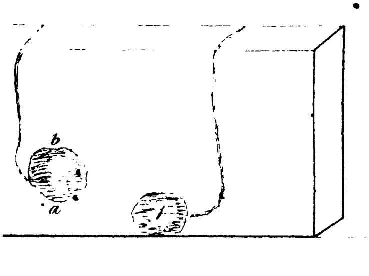
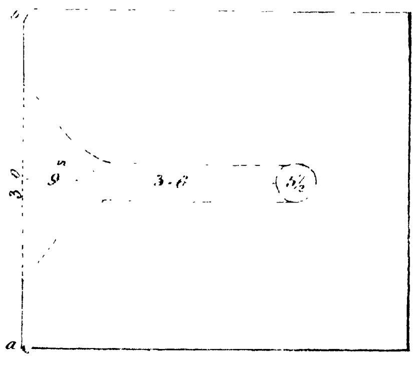


Fig. 4.




Section on ab.

200lbs.; of the seven shells that took effect, five were projected at an angle of 45°, and the remaining two at 75°. The effect produced by each shell is detailed in succession; and the position where each shell struck, is shown in the annexed sketches, on which are numbered, from one to seven, the several craters (broken surface round the shell) in the order they occurred.

*No.* 1 *Shell, at* 45°.—No. 1 shell merely grazed the right edge of the Dos d'ane so slightly, that its effect was of no value in determining the resistance of the material.

*No.* 2 *Shell, at* 45°.—No. 2 shell hit the left-hand gable of the roof, one foot from the ridge, and about its own diameter within the edge: about as much concrete was knocked off as would serve to fill a bushel basket. The shell glanced over six feet to the left, and fell with force sufficient to bury itself to the depth of its own diameter; whereas those shells that fell unimpeded, went usually to the depth of from five to seven feet; showing that a very material portion of the impetus had been overcome by the arch, which was in no way injured; but as the blow was given so very near the edge, the result was not conclusive.

*No.* 3 *Shell, at* 45°.—No. 3 shell took full effect on the outer or rear abutment, which it struck three feet within its outer edge; it pulverised the concrete to the depth of fourteen inches, and then bounded off over the butt to the distance of twenty-three yards. Three pieces of concrete were knocked off; the largest measured three feet in length, of irregular but average thickness of fifteen inches. The quantity contained in the three pieces would about fill three bushel baskets. The inside of the concrete was quite fresh, not being nearly dry.

*No.* 4 *Shell, at* 45°.—No. 4 shell struck the front face of the roof, just above the line formed by the meeting of the slope of the roof with the abutment; it indented to the depth of about one-third of its own diameter, and pulverised the concrete to the depth of ten inches: the crater was nearly circular, two feet in diameter; a crack commencing at the level of the crater, and about ten inches on the left of it, extended vertically towards the ridge, eight feet in length, and a corresponding crack, but of less width, showed through on the soffit of the arch. This shell lodged on the abutment at its inner edge.

*No.* 5 *Shell, at* 45°.—No. 5 shell struck on nearly the same level as No. 4, but four feet six inches to its right; it indented somewhat deeper than No. 4; the concrete was pulverised twelve inches, and the diameter of the crater was two feet six inches. A crack commencing rather above the level of the crater, and eighteen inches to its right, extended five feet vertically towards the ridge, and showed through on the soffit of the arch, but so finely as to be visible only on a close inspection. Another crack, in a horizontal direction, joined the centres of the two craters. This shell rebounded, and remained on the top of the abutment. This concluded the practice at 45° elevation.

*No. 6 Shell, at 75°.*—The first shell that took effect at 75°, struck within the crater formed by shell No. 4, and about six inches to the right of its centre. The effect was to increase the depth of the pulverised concrete from ten to fifteen inches, and the extent of the crater was enlarged from two feet diameter to nearly three feet. The cracks made by No. 4 were materially enlarged on both the outer and inner surfaces, and two fresh cracks were formed in a horizontal direction on the soffit of the arch. The one was situated about fourteen inches above the spring of the arch, and in extent about five feet; the other crack was about three feet above the former, and extending from the centre of the crater formed by the shell to the end of the casemate, and continued through the abutment nearly in the direction of the skew-back. This shell rebounded, and lodged twenty-eight feet from the front abutment.

*No. 7 Shell, at 75°.*—Shell No. 7, the second fired at 75°, struck the rear face of the roof three feet from the ridge, and equally distant from the two ends of the casemate; it pulverised the concrete to the depth of ten inches, and the crater was about two feet in diameter. A crack was formed, which, commencing about six inches to the right of the crater, extended vertically to the ridge, and beyond on the other side some distance; this crack showed through on the soffit. The shell bounded off to the distance of thirty-seven feet. It is to be observed, that in all cases, the cracks took place on one side or other of, and not directly from the centre of the several craters, which probably is to be attributed to the limited extent of the casemate, and to its having been so materially injured previous to the practice, by the unequal settlement of the abutments.

At this, the conclusion of the mortar-practice, the arch, though very materially shaken and injured, yet remained in such a state of security, as to justify, in case of necessity, that powder should be housed within it. And had this experimental arch been that of a magazine in a fortress besieged, and so unfortunate as to have been struck by five shells in succession, while unprotected by the usual means, yet would the powder within have continued uninjured.

*No.* 1 *Shot from a Twenty-four Pounder.*—The effect of shells on concrete having been ascertained by the above results, a twenty-four pounder was placed 250 yards from the casemate, and two shots were fired from it, which in succession took effect on the abutment. The position in which each shot struck is shown in the sketch annexed. The first shot penetrated to the depth of three feet nine inches and a half, including the diameter of the shot; the crater was nearly circular, and about three feet in diameter; two vertical cracks were formed on either side of the crater: the one on the right side went to the top of the abutment, showed through its upper surface to the roof, and appeared through on the inside.

*No.* 2 *Shot from a Twenty-four Pounder.*—The second shot struck as shown in the sketch, and penetrated to the depth of three feet ten inches and a half, including the diameter of the shot; the diameter of the crater was three feet, and of the section shown in the sketch No. 4. The cracks made by the first shot were very seriously increased and widened, from about one-eighth of an inch to three-quarters. The splinters from the concrete were not considerable; some stones however flew off to the distance of from forty to fifty yards.

15th June, 1835.

Since the experiment, two more twenty-four-pounder shot were fired with the service-charge on the 8th of June, in the presence of the Master-General, the effect of which was very considerable; and there is every reason to believe, a few more rounds would have broken down the arch. The effect of these two last shots is not shown in the drawing.

(Signed) GEO. J. HARDING,
Lieutenant-Colonel, Commanding Engineer.

*Present.*

Colonel Sir Alexander Dickson, K. C. B. Royal Artillery.
Colonel Williamson, C. B. Royal Artillery.
Colonel Drummond, C. B. Do.
Colonel Sir John May, K. C. B. Do.
Lieutenant-Colonel Harding, Royal Engineers.
Lieutenant-Colonel Paterson, Royal Artillery.
Captain Alexander, Royal Engineers,

SIR, Woolwich, 22nd June, 1835.

I have the honour to report, that the select Committee, in obedience to the orders of the late Master-General, conveyed in Colonel Sir Frederick Trench's letter of the 14th of April, caused the practice detailed in the enclosed memorandum, to be directed against the experimental concrete casemate, constructed in Woolwich marshes, a plan of which has been forwarded by the Engineer Department to the Board.

From the result of this practice, and after an attentive consideration of the subject, the Committee are of opinion, that the arch, considering the disadvantageous ground on which it was constructed, which had occasioned some degree of settlement, sustained the effect of the vertical fire directed against it in a very satisfactory manner; and they entertain every hope that Mr. Ranger's concrete will be found available for magazines of small dimensions, casemates, and those parts of revetements in fortresses that are least exposed to the effect of shot: but with the limited scale on which this experiment has been carried on, the Committee do not think, at present, they would be justified in recommending its application in the construction of large powder-magazines.

The letter from the Commanding Royal Engineer at Woolwich, and accompanying papers, are herewith returned.

I have the honour to be, Sir,

Your most obedient humble Servant,

(Signed) A. DICKSON,

Colonel. Lieutenant-Colonel, Royal Artillery.

Lieutenant-General the Right Hon. Sir H. VIVIAN, Bart. K.C.B.
&c. &c. &c.

## VI.—*Description of the Concrete Sea-Wall at Brighton, and the Groins which defend the Foot of it. By Lieutenant-Colonel* Reid, *Royal Engineers.*

The portion of the concrete sea-wall now constructing at Brighton, is 3000 feet in length: and this portion, together with what is already finished, will make a length of about 2000 yards of wall, the whole constructed of the sand and shingle from the beach alone, cemented by a water-lime from the neighbourhood, and mixed up with salt water, the water having been taken from the sea itself, until it was found more convenient to sink wells immediately at the back of the wall, where some fresh water becomes mixed with the salt.

The section of the wall is two feet and a half thick at the top, upright at the back, without counterforts, and battering in the front with a slope equal to one-third of the height. The foundation goes down to the chalk; and from the bottom to the top, it will in one part be seventy feet high, in many forty feet.

The lime is not ground, but slaked at the work, as it is going to be used, and first mixed by hand with three parts of sand. It is next wheeled to a pug-mill, and then intimately mixed with three parts more of shingle, after which it is wheeled away and thrown upon the wall. In its semi-fluid state, it is retained by boards ledged together. The wall being backed up as it proceeds, the rear ledges are easily supported by struts. To retain the front ones in their places, ties are used made of saw-plate iron, in strips passed through the boards, and keyed at the outer end. At the inner end, long iron needles pass through holes in the strips of saw-plate, and pin them to the ground. These needles and strips are easily drawn out and used again as the work proceeds. The surface sets the second day, and in ten days the ledged boards may be removed. It does not, however, harden sufficiently to bear the beating of the sea against it, for which reason the bottom of the wall is sheathed with two-inch beech planks for about six or eight feet high. These planks are placed inside of piles, and the piles are tied into the mass of the wall by iron ties of one and a half inch diameter, and ten feet long. A violent gale of wind accompanying a spring tide, on the 12th of October, 1836, had a powerful effect upon this sheathing, besides injuring the face of the wall above it. It is supposed, that from the sheathing vibrating from the constant blows of the surge against it, first particles of sand got in behind it, and next small pebbles, shaking downwards as the vibrations continued, until the coarsest shingle was admitted, and the sheathing was started and removed along a considerable length, from four to six inches from the wall, breaking some of the iron ties, and forcing off many nuts. The sea washed off the surface of a considerable portion of the new wall, in places to the depth of a foot. At the same time it threw the shingle up upon the top of the wall, to the height of eighteen or twenty feet, where it lay after the gale, in some places six and nine inches thick.

As the sea is encroaching along nearly the whole of the southern coast of England, this wall, at least in its new state, cannot resist the beating of the surge against it; its security depends upon the system of groins maintained in its front. These groins run perpendicularly to the line of coast, and collect the shingle, at the places where they are constructed, and retain it there, provided they are kept in repair; but not otherwise. The prevailing winds being westerly, and the highest seas rolling from the south-west, the pebbles of the beach are gradually carried to the eastward, and a constant supply is furnished by the falling away of the cliffs. On this coast, therefore, groins so constructed, as to prevent the moving shingle from passing to the eastward, cause it to accumulate. An idea may be formed of the quantity moving along, from west to east, at Brighton, from the fact of the whole of the gravel for the concrete wall having been taken from the beach; and there being now a greater quantity in front of it than when the work began a year and a half ago. The quantity used in the new wall is at present about 30,000 cubic yards. When the wall is finished, the accumulation of shingle will remove high water-mark a few yards, so as to leave the wall itself protected; and this accumulation has already taken place in front of the portion finished.

As the sea has washed away many of our coast defences, and threatens many more, it would be interesting to know its effects upon different parts of the coast; for they most probably vary from local circumstances. The sand and gravel of the east coast may be expected to move to the southward, as the highest seas roll from the north-east; and if this be the case, it may account for the accumulations of sand and gravel at Dover and Dungeness.*

* The general direction of the drift of sand and shingle along the coast, seems to depend more upon the set of the flood-tide than that of the wind; though the latter, of course, exerts

At Brighton, wherever the groins are complete the shingle accumulates; but if a plank be removed, or a hole broken, it passes on to the eastward, and the plane between the groin opened, and the one to the westward of it, soon becomes lowered to the level of the opening.

It is also said that, notwithstanding all the pains taken to stop the shingle, a considerable quantity is carried past the groins. It is supposed that when the sea is violently agitated, the pebbles becoming suspended in it are floated over the groins in deep water.

It has been proposed to excavate a harbour at Hastings (forty miles east of Brighton,) out of a flat piece of land close to the town. If the progress of this shingle eastward be constant, it would have to pass the mouth of such a harbour, and would impede its entrance; and if the common mode of clearing the harbour-mouth by a backwater were adopted, it would but force the shingle to take a longer route; forming shoals. This example is only introduced to prove how interesting it may become to observe and record the movement of the sand and gravel along the coast, and particularly in its passage across the mouths of rivers and harbours.

Shoals at the mouths of rivers and harbours, may perhaps be found to bear a comparison in their movements with clouds on the tops of mountains, so long considered stationary, because for a whole day they have not *appeared* to move; but which are now known to be the atmospheric vapour, which in its passage over the cold top of a mountain is condensed for the moment, to be immediately again dissolved into invisible vapour after passing the summit; so shoals at the mouths of rivers and bar-harbours may be constantly gaining sand on one side, and giving it off on the opposite: and should this be found to be the case, then such a construction might be given to piers as to allow a free passage to the moving sand and gravel.

The lime used in the concrete wall is taken from a pit near Bycombe, eight miles north of Brighton, and is a weak water-lime. The lime used for

some influence, and in case of heavy gales sufficient to neutralize the action of the tide, and to accumulate banks of sand and gravel in spots which would otherwise have been kept free, as for instance at the mouth of Dover harbour. The flood-tide sets up the channel, past Dover and Deal, running northward; at Harwich, and all along the east coast, it sets to the southward. May not the Goodwins, and other banks in that neighbourhood, be produced by the meeting of the two tides?—Ed.

a row of houses* now building of concrete, at Brighton, is from the pit of Southerham, near Lewes, and is also a water-lime. According to Mr. Mantell, (who has so long studied the geology of the south-east of England) both these pits are in the strata of chalk-marl, lying under the lower chalk formation; and it is to be found at the northern escarpments of the South Downs, and the southern of the North Downs. These two limes are similar to the Dorking and the Halling (near Rochester) limes: and it will be interesting to ascertain whether all the limes burnt from the same stratum have the same property.

It has been stated above, that the great sea-wall (at least in its new state) cannot resist the beating of the surge against it; and that its security depends upon the system of groins in its front. It is however deserving of remark, that some of the same concrete has been used, near low water-mark, to fasten some piles at the lower extremity of one of the groins, which were loosely placed in large holes in the chalk bed of the sea; and which concrete was poured in, in its usual semi-fluid state. The place where it is, is almost always covered by the sea; yet it has become so hard that it resembles rock; and it was not found practicable, on examining it, to detach a single pebble from the mass, without procuring iron tools.

Another trial of laying this concrete under sea-water, has been successfully made at the outer end of the Brighton chain-pier. Some time back, large artificial stones of concrete made of the Bycombe lime, were moulded, and after being allowed to harden on shore, they were placed at the feet of the outermost set of piles of the Brighton chain-pier, to aid in securing them. These also have become very hard, and are now encrusted with shell-fish; whilst the chalk thrown in at the same place is soft and pulpy, and evidently wearing by the action of the sea.

These experiments led Mr. Wright, late surveyor to the Brighton Commissioners, and now employed upon the Dover railway, to propose to con-

* A row of concrete houses, of good elevation, are now nearly finished on the westerd road, Brighton. They are building by Mr. Ranger, the patentee for making artificial stone with hot water. The walls are fifty feet high, from the bottom of the cellars to the top: they are twenty inches thick at bottom; the greater part being built of the patentee's artificial stone (being concrete cast in moulds); but much is also made like the sea-wall, viz. between two sets of boards, which retain the semi-fluid concrete in the form of the wall until it hardens. The arches of the cellars are all of concrete made of sea gravel.

struct a substantial groin of concrete to be coped with stone, and having sides with gradual slopes. The Brighton Commissioners have not authorized this trial, however, to be made, which is to be regretted.

The contract price of the concrete in the great wall is fourteen shillings for each square reduced to fourteen inches thick, the Brighton mode of measuring, which is equal to three shillings and fourpence a cubic yard.

(Signed) W. REID,

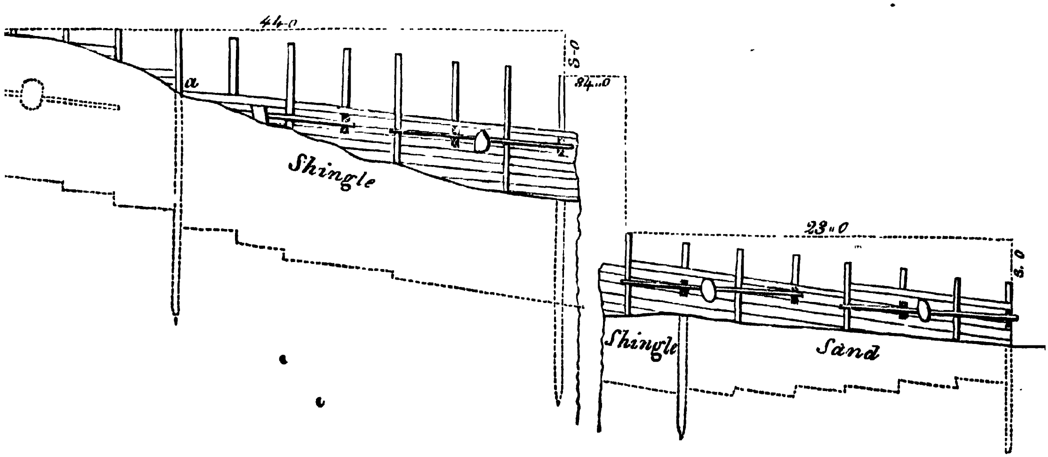
Lieutenant-Colonel, Royal Engineers.

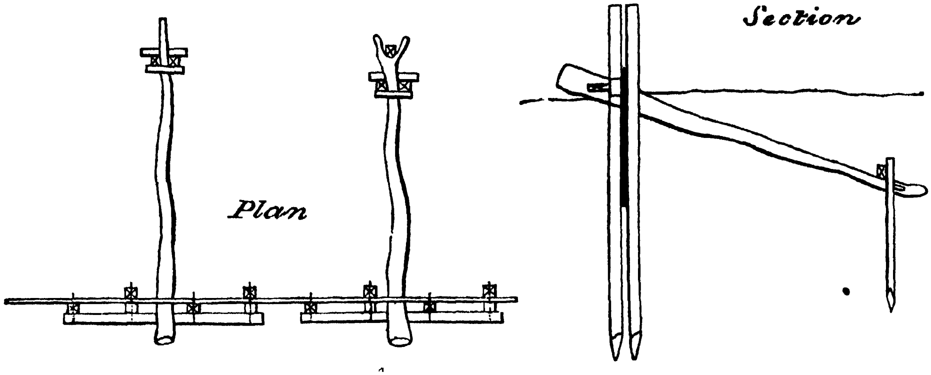
## VII.—*Description of the Groins used on the Coast of Sussex, for preventing the Encroachment of the Sea. By Lieutenant* LUXMORE, *Royal Engineers.*

Extract of a Letter from Lieutenant Luxmore to Lieutenant-Colonel Pasley, dated East Bourne, 31st October, 1822.

"MY attention has been drawn to the subject, by having had to superintend the construction of a groin in front, and for the protection of the circular redoubt at this place, about 180 feet of the revetement of the counter-scarp of which work is at this moment exposed, to the depth of from eight to eleven feet; the state of the beach in front of it, before the construction of this last groin, which is the centre one of five, was nearly as represented in the elevation; the pile at *b* touches the buttress of the counter-scarp, and as a proof of its efficacy, the high-water mark, then at *a*, has been forced nearly fifty feet further out, by the accumulation of shingle.

"This description of work, which is of a local nature, was entirely novel to me: and not having had the advantage of observing its effects during the winter, as well as summer season, I have, in laying down the general rules for its construction, been guided more by the information of the clerk of works, (Mr. Dumbrill) whose long experience and other qualifications render him, I conceive, fully capable of forming a correct opinion on the subject, than by my own short experience and observation."






A Short Description of the Use and Construction of Groins.

A groin is a frame of wood-work, constructed across a beach, between high and low water, perpendicular to the general line of it, either to retain the shingle already accumulated, to recover it when lost, or to accumulate more at any particular point.

The component parts of a groin are piles, planking, land-ties, land-tie bars, blocks, tail-piles and keys, and screw-bolts.

The length of a groin depends on the extent, and the requisite strength of its component parts on the nature of the beach on which it is to be constructed.

Those at East Bourne on the coast of Sussex, of which the following is more particularly a description, are from 150 to 250 feet in length; and the beach at that place being very rough, consisting of coarse heavy shingle and large boulders, they require to be composed of proportionably strong materials to resist its force.

The piles are from twelve to twenty-five feet long, and eight by six inches and a half scantling, shod with iron.

The planking is in lengths of eight, twelve, and sixteen feet, two inches and a half thick, and with parallel edges.

The land-ties are of rough timber from twenty to twenty-five feet long, and large enough at the butt end to receive the bars.

The land-tie-bars are thirteen feet six inches long, and twelve by five inches scantling.

The land-tie bar-blocks are about two feet long, and of the same scantling as the piles.

The land-tie tail-keys are about two feet six inches long, and six by two inches and a half scantling.

The above materials are of oak or beech.

The screw-bolts are of inch round iron, two feet nine inches and a half, and two feet one inch and a half long, in equal proportions.

The relative proportions of the component parts are four piles, one land-tie with tail-piles and keys, one land-tie-bar with two blocks, two long and two short bolts, about 180 square feet of planking, and about 140 six-inch spikes for every sixteen feet in length; and the expense of a groin, constructed with materials of the above dimensions, may be calculated at about *30l.* for the same length.

## General Rules observed in the Construction.

When the object, in constructing a groin, is to recover shingle, or accumulate more, the first pile is driven at the high-water mark of neap tides, leaving its top level with that of spring tides. The next is driven at the point, on the sands beyond the bottom of the shingle, to which the groin is to extend, leaving about four feet of it out of the beach.

The tops of these two piles may be taken for the general slope of the groin, unless the beach should be very steep, and much curved, in which case it becomes necessary to follow its curvature in some degree.

From the high-water mark of neap tides, the piles are carried back nearly level to that of spring tides, and as much further as may be considered necessary.

The piles are driven four feet asunder from centre to centre, and so as to admit the planking between them alternately, and they should be sunk about two-thirds of their length.

The longest piles are placed between the high-water mark of neap tides, and the bottom of the shingle, particularly from twenty to forty feet below the former point.

The planking is, if possible, carried down to about two-thirds from the tops of the piles, and kept parallel with them.

The land-ties are placed about one-third from the top of the planking, (supposing the latter to commence from the tops of the piles,) and their tails are sunk to the level of the bottom of the planking, or as nearly so as possible.

The method of uniting the component parts of a groin is shown by the accompanying plan, elevation, and section.

The land-ties have, in some cases, been placed on either side alternately, in which case one-fourth more land-ties, bars, &c. are required in the construction, because it then becomes necessary for the land-ties to overlap. The principal reason, however, for giving the preference to placing all the land-ties on the westernmost side is, that when placed alternately, those on the easternmost side are, from the general prevalence of westerly winds, liable to be left wholly exposed; and when in that state for any length of time, they are apt to free themselves from their tale-piles, and endanger the safety of the groin.

The planking should only be carried up to about one plank above the land-ties at first, and afterwards gradually completed, as the shingle accumulates, which should pass over it at about high water, so as to form itself on the same level on both sides at the same time; for when the planking is carried up too high at first, the shingle is removed from the leeward side, by the general motion of its surface, in the direction in which the sea is running, before it has accumulated high enough on the windward side to pass over and supply the deficiency, so that when it does pass over, the reaction of the sea on the leeward side produced by the then difference of level, prevents it from settling there; and before this error was discovered, it frequently happened, when the wind continued in the same quarter for any length of time, that the planking became exposed to the very bottom on the leeward side, the shingle accumulated on the windward side, passed under it, and the groin becoming undermined was soon destroyed.

When a set of groins are constructed, they are placed from 50 to 100 feet or more apart, according to their length.*

(Signed) T. C. LUXMOORE,

Lieutenant, Royal Engineers.

* The general question of protecting the coast against the action of the sea, is very interesting to Engineers, and not very well understood in this country: any fact bearing on this subject, will be very acceptable. The Dutch coast affords many specimens of this kind of work, varied according to localities, and according to the nature of the action exerted by the sea upon the shore.—ED.

## VIII.—*Table for determining Altitudes with the Mountain Barometer. Computed by* Samuel B. Howlett, *Esq. Chief Draftsman, Ordnance.*

SIR, 83½ Pall-Mall, 1st February, 1837.

Having discovered that a table for determining altitudes with the barometer, given in a second edition of a 'Treatise on Mathematical Instruments,' and also in 'White's Ephemeris,' is founded upon a misconstruction of a valuable formula given by Mr. Francis Baily, and that it produces most fallacious results in all cases where the temperature of the barometer is higher at the upper station than at the lower, I may perhaps, without offence to any party, be allowed to forward to you, as requested, for the purpose of being inserted in the 'Professional Memoranda' about to be published, a copy of an entirely new table, with directions for its use, which I have prepared from that formula

2. If the second example annexed to my table be computed, it will produce the following results:

| | | | Ft. | In. |
|---|---|---|---|---|
| Altitude | according to | General Roy | 391 | 5 |
| ,, | ,, | Sir George Shuckburg | 390 | 4 |
| ,, | ,, | Dr. Hutton | 390 | 10 |
| ,, | ,, | Tables by Messrs. Jones | 390 | 7 |
| ,, | ,, | Table computed by S. B. Howlett | 391 | 4 |
| | | Mean | 390 | 11 |
| ,, | ,, | The defective table in question | 359 | 10 |
| | | Error | 31 | 1 |

3. The brief directions, too, at the foot of the defective table, contain two important errors; and not only are these errors copied into the Ephemeris for this year, but two more unlucky errors are added, probably by the printer.

4. In my table, the two columns of B might be merged into one, by taking the mean of the two and giving directions for changing the sign; but as they stand, they are easier to use, and somewhat more exact than if one column only were given. As, however, in the defective table the numbers are only computed to

five places of decimals, B might be used as it is, making it positive or negative, according to the case; but no such application is pointed out or implied in either of the publications to which I have adverted. Here then lies the error, which appears to have entirely escaped notice.

5. I have computed the table to seven places of decimals, which will, no doubt, be thought an unnecessary degree of nicety by those who suppose the barometer to be so imperfect an instrument, that not only a few inches but a few feet can be of no consequence in tables by which the observations are computed. But so far from this being the case, the mountain barometer, when skilfully used and the corrections properly applied, is a remarkably perfect instrument. I prefer those with iron cisterns, and find that they agree, generally, in giving the same altitude, when used side by side under the same circumstances, to within two feet. I have just rejected one because it would not enable me to obtain an altitude within nine feet of the truth. I am now, however, only referring to the degree of accuracy of which this truly beautiful little instrument is capable, in order to show that it is worthy of being met by very nicely calculated tables. The mode of using the instrument, so as to ensure accurate measurements, is not my present object.

6. It may be here remarked, that the tables by Messrs. Jones and Son, of Charing Cross, are particularly convenient, as the altitudes may be taken out by inspection, without the aid of logarithmic tables. In great heights, however, there will be found some discrepancy between results obtained from these tables and from the formula given by Baily; nor is there any correction for latitude.

7. If the barometer were very much required in the service, it would be desirable to appoint two very accurate observers; first to take a section across a mountain, such as Snowdon, with a spirit level, and then to verify both the barometer and the tables by numerous simultaneous observations.

8. In further explanation of this object, I subjoin a letter from a highly talented and excellent young man in the Nautical Almanac Office.

I am, Sir,

Your obedient humble Servant,

SAML. B. HOWLETT,

Chief Draftsman.

Lieutenant Denison,

Royal Engineers.

MY DEAR SIR, Somerset House, 27th January, 1837.

I AM happy I have it in my power to answer the queries in your letter with regard to the barometric tables.

From your data, the altitude of the hill, according to Simms, is 359 feet 10 inches; and as this result agrees exactly with yours, it is not at all probable that either of us have fallen into any error of calculation.

Simms has computed his table from the formula given by Mr. Francis Baily, in page 111 of his valuable collection of astronomical formula and tables, from various authorities, and which formula was deduced by rigorous investigation, and stands as follows:

$$\text{Diff. of alt.} = 60345 \cdot 51 \left\{ 1 + \cdot 00111111\,(t + t' - 64^\circ) \right\}$$
$$+ \log. \left\{ \frac{\beta}{\beta'} \cdot \frac{1}{1 + \cdot 0001\,(T - T')} \right\} + \left\{ 1 + \cdot 002695 \cos.\, 2\,\phi \right\}$$

Where $t$ = detached thermometer, $\beta$ = height of barometer, $T$ = attached thermometer } at lower station.

$t'$ = detached thermometer, $\beta$ = height of barometer, $T'$ = attached thermometer } at upper station.

$\phi$ = latitude of place of observation.

The table which he gives is much the same as Simms's, and both are correct, where the temperature is greater at the lower than at the upper station; but when the contrary happens, as in the case of your observations, then the number B is erroneous; the reason of which is, that the difference $(T—T')$ then becomes negative, and must be used as such in the computation of B from "Log. $\left\{1 + \cdot 0001\,(T—T')\right\}$" which renders an additional table necessary.

Your example computed according to Baily's formula, as it should be applied, makes the altitude of the hill = 391 feet 10 inches, agreeing to within a few inches of the result obtained by General Roy's formula.

Your's, very truly,

(Signed) R. BULLEN.

SAMUEL B. HOWLETT, Esq.

Table for determining Altitudes with the Barometer. Computed by Samuel B. Howlett, Chief Draftsman, Ordnance, from the formula given by F. Baily, Esq.

| Thermometers to the Barometers. | | | Thermometers in the open air. | | | | | | | | Latitude of the Place. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | | S | A | S | A | S | A | S | A | L | C |
| D | Ther. highest at lowest station. | Ther lowest at lowest station. | ° | | ° | | ° | | ° | | ° | |
| | | | 40 | 4·7689067 | 75 | 4·7859208 | 110 | 4·8022936 | 145 | 4·8180714 | 0 | 0·0011689 |
| | | | 41 | ·7694021 | 76 | ·7863973 | 111 | ·8027525 | 146 | ·8185140 | 3 | ·0011624 |
| ° | | | 42 | ·7698971 | 77 | ·7868733 | 112 | ·8032109 | 147 | ·8189559 | 6 | ·0011433 |
| 0 | 0·0000000 | 0·0000000 | 43 | ·7703911 | 78 | ·7873487 | 113 | ·8036687 | 148 | ·8193975 | 9 | ·0011117 |
| 1 | ·0000434 | 9·9999566 | 44 | ·7708851 | 79 | ·7878236 | 114 | ·8041261 | 149 | ·8198387 | 12 | ·0010679 |
| 2 | ·0000869 | ·9999131 | 45 | ·7713785 | 80 | ·7882979 | 115 | ·8045830 | 150 | ·8202794 | 15 | ·0010124 |
| 3 | ·0001303 | ·9998697 | 46 | ·7718711 | 81 | ·7887719 | 116 | ·8050395 | 151 | ·8207196 | 18 | ·0009459 |
| 4 | ·0001737 | ·9998262 | 47 | ·7723633 | 82 | ·7892451 | 117 | ·8054953 | 152 | ·8211594 | 21 | ·0008689 |
| 5 | ·0002171 | ·9997828 | 48 | ·7728548 | 83 | ·7897180 | 118 | ·8059509 | 153 | ·8215988 | 24 | ·0007825 |
| 6 | ·0002605 | ·9997393 | 49 | ·7733457 | 84 | ·7901903 | 119 | ·8064058 | 154 | ·8220377 | 27 | ·0006874 |
| 7 | ·0003039 | ·9996959 | 50 | ·7738363 | 85 | ·7906621 | 120 | ·8068604 | 155 | ·8224761 | 30 | ·0005848 |
| 8 | ·0003473 | ·9996524 | 41 | ·7743261 | 86 | ·7911335 | 121 | ·8073144 | 156 | ·8229141 | 33 | ·0004758 |
| 9 | ·0003907 | ·9996090 | 52 | ·7748153 | 87 | ·7916042 | 122 | ·8077680 | 157 | ·8233517 | 36 | ·0003615 |
| 10 | ·0004341 | ·9995655 | 53 | ·7753042 | 88 | ·7920745 | 123 | ·8082211 | 158 | ·8237888 | 39 | ·0002433 |
| 11 | ·0004775 | ·9995220 | 54 | ·7757925 | 89 | ·7925441 | 124 | ·8086737 | 159 | ·8242256 | 42 | ·0001223 |
| 12 | ·0005208 | ·9994785 | 55 | ·7762802 | 90 | ·7930135 | 125 | ·8091258 | 160 | ·8246618 | 45 | ·0000000 |
| 13 | ·0005642 | ·9994350 | 56 | ·7767674 | 91 | ·7934822 | 126 | ·8095776 | 161 | ·8250976 | 48 | 9·9998775 |
| 14 | ·0006076 | ·9993916 | 57 | ·7772540 | 92 | ·7939504 | 127 | ·8100287 | 162 | ·8255331 | 49 | ·9998372 |
| 15 | ·0006510 | ·9993481 | 58 | ·7777400 | 93 | ·7944182 | 128 | ·8104795 | 163 | ·8259680 | 50 | ·9997967 |
| 16 | ·0006943 | ·9993046 | 59 | ·7782256 | 94 | ·7948854 | 129 | ·8109298 | 164 | ·8264024 | 51 | ·9997566 |
| 17 | ·0007377 | ·9992611 | 60 | ·7787105 | 95 | ·7953521 | 130 | ·8113796 | 165 | ·8268365 | 52 | ·9997167 |
| 18 | ·0007810 | ·9992176 | 61 | ·7791949 | 96 | ·7958184 | 131 | ·8118290 | 166 | ·8272701 | 53 | ·9996772 |
| 19 | ·0008244 | ·9991741 | 62 | ·7796788 | 97 | ·7962841 | 132 | ·8122778 | 167 | ·8277034 | 54 | ·9996381 |
| 20 | ·0008677 | ·9991305 | 63 | ·7801622 | 98 | ·7967493 | 133 | ·8127263 | 168 | ·8281362 | 55 | ·9995995 |
| 21 | ·0009111 | ·9990870 | 64 | ·7806450 | 99 | ·7972141 | 134 | ·8131742 | 169 | ·8285685 | 56 | ·9995613 |
| 22 | ·0009544 | ·9990435 | 65 | ·7811272 | 100 | ·7976784 | 135 | ·8136216 | 170 | ·8290005 | 57 | ·9995237 |
| 23 | ·0009977 | ·9990000 | 66 | ·7816090 | 101 | ·7981421 | 136 | ·8140688 | 171 | ·8294319 | 58 | ·9994866 |
| 24 | ·0010411 | ·9989564 | 67 | ·7820902 | 102 | ·7986054 | 137 | ·8145153 | 172 | ·8298629 | 59 | ·9994502 |
| 25 | ·0010844 | ·9989129 | 68 | ·7825709 | 103 | ·7990681 | 138 | ·8149614 | 173 | ·8302937 | 60 | ·9994144 |
| 26 | ·0011277 | ·9988694 | 69 | ·7830511 | 104 | ·7995303 | 139 | ·8154070 | 174 | ·8307238 | 63 | ·9993115 |
| 27 | ·0011710 | ·9988258 | 70 | ·7835306 | 105 | ·7999921 | 140 | ·8158523 | 175 | ·8311536 | 66 | ·9992161 |
| 28 | ·0012143 | ·9987823 | 71 | ·7840098 | 106 | ·8004533 | 141 | ·8162970 | 176 | ·8315830 | 69 | ·9991293 |
| 29 | ·0012576 | ·9987387 | 72 | ·7844883 | 107 | ·8009142 | 142 | ·8167413 | 177 | ·8320119 | 75 | ·9989852 |
| 30 | ·0013009 | ·9986952 | 73 | ·7849664 | 108 | ·8013744 | 143 | ·8171852 | 178 | ·8324404 | 81 | ·9988854 |
| 31 | ·0013442 | ·9986516 | 74 | ·7854438 | 109 | ·8018343 | 144 | ·8176285 | 179 | ·8328686 | | |

Make R = log. $\beta$ — (B + log. $\beta'$.)

The log. diff. of altitude in English feet = A + C + log. of R.

$\beta'$ = height of the barometer at the upper station.

$\beta$ = height of the barometer at the lower station.

S = sum of the detached thermometers at the two stations.

D = difference of the attached thermometers at the two stations.

L = latitude of the place of observation.

The degrees of temperature according to Fahrenheit.

$$A = \log.\left\{ 60345{\cdot}51 \times \left[1 + {\cdot}00111111\,(t + t' - 64^\circ)\right]\right\}$$

$$B = \log.\left\{1 + {\cdot}0001\,(T - T')\right\}$$

$$C = \log.\left\{1 + {\cdot}002695 \cos. 2\phi\right\}$$

$\phi$ = the latitude of the place of observation.

$T$ = the temperature of the mercury } at the lower station.
$t$ = the temperature of the air }

$T'$ = the temperature of the mercury } at the upper station.
$t'$ = the temperature of the air }

Directions for using the foregoing table.

To the log. of the height of barometer at the upper station, add the number from the proper column in B opposite the difference of the degrees read on the attached thermometers at the two stations, and subtract their sum from the log. of the height of the barometer at the lower station, and call this result R; then to the log. of R add the number in A opposite the sum of the degrees read on the detached thermometers at the two stations, and also add the number in C opposite the latitude of the place, and the sum, rejecting the tens from the index, will be the log. difference of altitude in feet.

EXAMPLE 1.

| Station. | Barometer. | Attach. Ther | Detach. Ther. |
|---|---|---|---|
| Lake ......... | 29 ·950 | 50° | 49° |
| Mountain...... | 27 ·474 | 44 | 45 |
| Latitude 55° | | | |

| | |
|---|---|
| Log. of 27 ·474........................... | 1 ·4389219 |
| B..... 50° — 44° = 6° .................... | 0 ·0002605 |
| | 1 ·4391824 |
| Log of 29 ·950 ........................... | 1 ·4763968 |
| R.......................................... | 0 ·0372144 |
| Log of R.................................. | 8 ·5707110 |
| A .... 49° + 45° = 94° .................... | 4 ·7948854 |
| C .... 55°................................. | 9 ·9995995 |
| Log. diff. of altitude...................... | 3 ·3651959 = 2318 ·44 feet. |

EXAMPLE 2.

| Station. | Barometer. | Attach. Ther. | Detach. Ther. |
|---|---|---|---|
| Wharf ........ | 29 ·799 | 39° | 37° 5′ |
| Hill .......... | 29 ·384 | 45 | 46 0 |
| Latitude 51° 30′ | | | |

| | |
|---|---|
| Log. of 29 ·384 ............................ | 1 ·4681109 |
| B....45° − 39° = 6° ...................... | 9 ·9997393 |
| | 1 ·4678502 |
| Log. of 29 ·799 ............................ | 1 ·4742017 |
| R........................................... | 0 ·0063515 |
| Log. of R.................................. | 7 ·8028763 |
| A.... 46° + 37° 5′ = 83° 5′.................. | 4 ·7899541 |
| C.... 51° 30′............................... | 9 ·9997367 |
| Log. diff. of altitude ...................... | 2 ·5925671 = 391 ·35 feet. |

## IX.—*A new Method of making Perspective Drawings from Plans and Dimensions.* *By* SAMUEL B. HOWLETT, *Chief Draftsman, Ordnance.*

A B C, *fig.* 1, is a square, of any size, having a line of small holes, B C, at right angles with the edge A B, the centre of the lowest hole, B, being in a line with A B. This square may be formed by attaching a slip of wood, or brass, to either end of a flat ruler, in such a way that the under face of the square may lie flat upon the paper; or, as the pattern T-square has the stock and blade flush on one side, it may be most conveniently made available for this purpose, by perforating one half of the stock with a few small holes, as those in the line B C, at about a quarter or half an inch apart.

D E F is the plotting-square, having its edge, D E, divided into any number of equal parts, as twenty, thirty, or forty in an inch, and figured on both sides, that the square may be used with its edge towards the right or left. The pattern angle, proper to be used with the T-square for general purposes, is also suitable for this purpose, as, besides several scales on its sides useful in drawing architecture, its edge is graduated in the manner described.

G H are two weights, of any kind, to each of which is attached a silk thread, waxed, passing through a hole to the under part of the weight, so that it may be pressed close down upon the paper. A yard or two of silk may be wound round the handle, which serves as a sort of reel, by which the length of the thread may be regulated at pleasure.

I, *fig.* 2, is a flat ruler, such as a one or two foot scale, resting against two common pins, *k l*, forced into the board, allowing the ruler to be moved and replaced.

Let it be required to put the object M N O, *fig.* 1, into perspective, the height of which is 170, in terms of the edge of the plotting-square, as it would appear upon the picture plane, P Q, the observer's eye being at R, at a height above the ground or datum plane, equal, say to B R.

Through the hole R, then pass from underneath the ends of the threads,

*Fig. 1.*

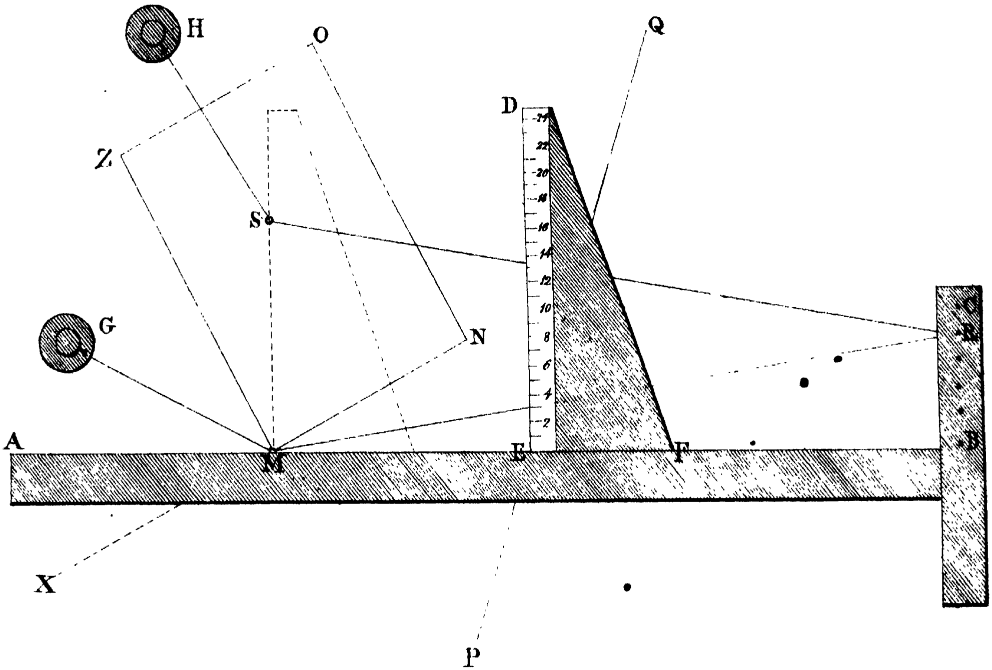
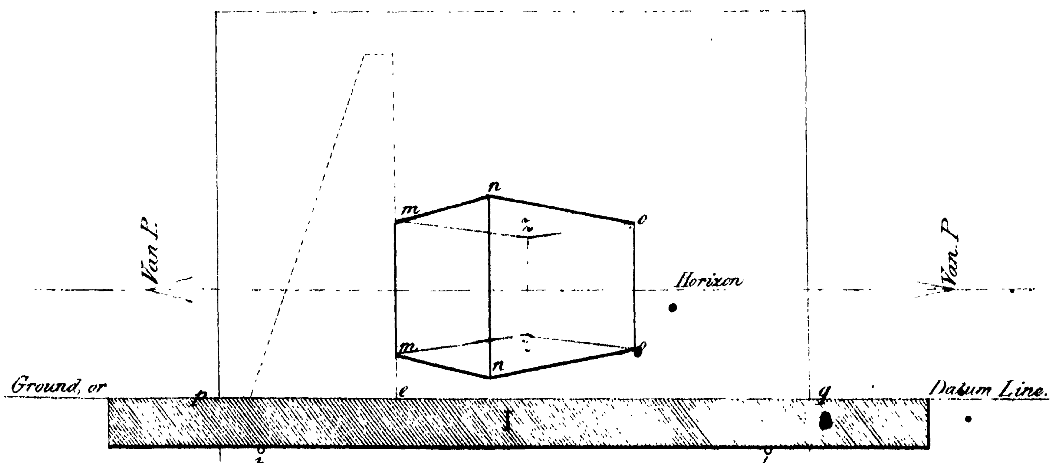

H
O
Q
D
Z
S
G
N
A
M
E
F
C
R
B
X
P

*Fig. 2.*


n
m
o
Van. P.
Horizon
Van. P.
m
n
o
Ground, or
p
e
q
Datum Line.
I

and fix them by a knot; and through the hole B, and the station of the observer, force a common pin into the board, to form an axis. Instead of fixing the threads by a knot, each thread may have a small loop at the end, which loop, when passed through the hole, may be fixed by putting it over the head of the pin at B.

At the angle M of the object, fix a fine protracting needle, against which turn the arm A B of the square, having previously strained round the needle the silk R M G. Keeping the square in this position, place the plotting-square against M, as shown by the dotted lines, and at 170 fix another needle, S, and pass round it the silk R S H. Now, at the point where the edge A B of the square cuts the picture P Q, place the corner, E, of the plotting-square, and then will the space between the silks, where they cut the edge of the plotting-square at 30 and at 135, be the apparent height and position of the line M S, which represents the vertical angle of the object at M.

To transfer this apparent height and position to the picture, *fig.* 2, proceed thus:—With the compasses, take the distance Q E, *fig.* 1, and holding one leg of the compasses at *q*, *fig.* 2, slide the plotting-square, as shown by the dotted lines, against the other at *e*, and then, at 135, make a faint dot and draw the pencil down to 30, at which make another dot, and then will the line *m m* be the true representation of the line of the original object at M, *fig.* 1.

By the same process, find the other parts of the object, and connect the proper points by drawing lines.

Supposing the object M N O, *fig.* 1, to be a building, it will be necessary to find the vanishing point of its faces, to guide in drawing the doors, windows, and other details. In all cases, to find the vanishing point of a plane, nothing more is necessary than to produce the top and bottom lines of that plane, as drawn by this instrument, until they intersect in the horizon or otherwise; but if the point should be very remote, then it will be seen that the requisite data is afforded by which to set any instrument for drawing radial lines. Should the sloping lines of the plane be too short to give the intersection so accurately as desired, then produce those lines in the plan, and find the position in the picture of more distant points in those lines; as, for instance, the line N M might be produced, and a point X found instead of M.

When it is required to work from any particular plotting-scale, proceed thus:—Suppose the height of the object, M S, *fig.* 1, to be fifty feet six inches, instead of marking off the height from the plotting-square, merely place a needle any where against its edge, and then against M and this needle place the scale, and holding the division of six inches at M, insert the needle, S, at the fifty feet.

By this method of obtaining the general outline of an object, with the hint as regards finding the vanishing points to guide in drawing the details, every description of object, how complicated soever, may be readily put into perspective in the neatest and most accurate manner.

Instead of using two threads, it will be better, at first, to use only one; and to learn this method, it is recommended to begin by first finding the projection of one point only, as, for instance, the point M, then by the same kind of process to find another point, as N, and so on; and then, by connecting these points together on the plan, and the corresponding points in the projection, it will be found that a power has been acquired of putting any required form into perspective. For, having the power of finding the position of any given point by one simple process, and as all outlines are, in fact, made up of points, it follows that every outline may be thus drawn; and that, too, without the entanglement and confusion of a great number of waste lines.

In drawing perspective, it is of course a condition, that the place of every essential point shall be given upon the horizontal datum plane, and also its height above that plane. These essentials being obtained, which in most cases is the chief difficulty, the whole art of drawing perspective is reduced, by the method here given, to a mere straightforward operation of common sense.

In a report by Dr. Olinthus Gregory, Captain Macaulay, and Mr. Christie, the following opinion is given:—" We, the undersigned, have, agreeably to the directions of the Master-General of the Ordnance, examined an apparatus invented by Mr. Samuel B. Howlett, and which he denominates 'Perspective Squares for making Drawings from Plans and Dimensions.' We have also received his oral as well as written description of the principles of his contrivance, and have witnessed its application to a specific case. We regard Mr. Howlett's apparatus as ingenious, simple, and founded upon correct principles; and think that it is calculated to facilitate the labour of draftsmen, of architects, and engineers, when they wish to make perspective drawings from given or assigned plans and known heights of buildings, &c., whether simple or complex in their exterior. In this view, it is a great advantage of Mr. Howlett's instrument, that its use may be learned in a quarter of an hour, by any person who has a general acquaintance with plan drawing."

SAML. B. HOWLETT,

Chief Draftsman.

83½, Pall Mall,
1st Feb. 1837.

## X.—*A new Field-Protractor and Sketch-Book.* *By* SAMUEL B. HOWLETT, *Chief Draftsman, Ordnance.*

THE most suitable instrument for taking the bearings of objects in military sketches, or for making a survey of a line of road or railway, is the surveying, or prismatic compass. With this instrument, and either the land-chain or pacing, or both combined, a survey of an extensive tract may be made with great accuracy, provided the lines of measurement be well arranged. The survey may be entered in a field-book, and the details sketched after the general outlines have been plotted; but, in many cases, it is desirable to plot the work in the field, so as to bring home the drawing complete. It is for this latter purpose that the field-protractor and sketch-book are contrived.

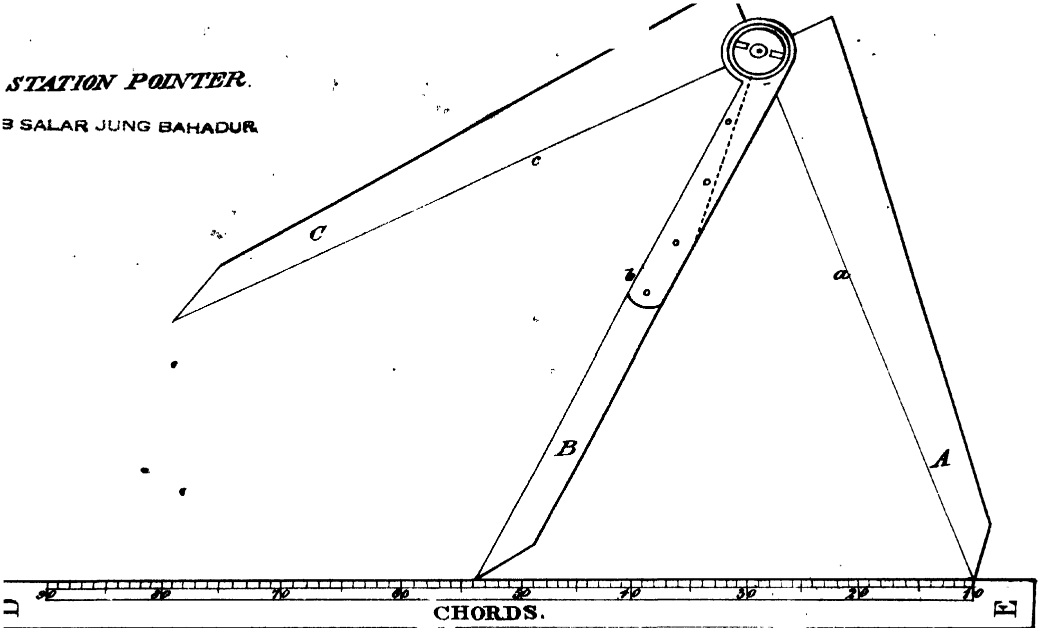
The proper paper for the sketch is medium bank-post, as it admits of being folded without injury. At distances of about half an inch apart, lines are to be ruled across the paper, perfectly parallel, with hard pencil or faint ink, to represent meridians. The paper is folded over the inner flap of the book, to keep it steady; and the cover, being a little larger than the flap, preserves the paper from injury. Supposing the work to lie west of the point where the survey is to commence, the right-hand edge of the sheet should be folded uppermost, and so placed in the book that the meridians may be vertical, the upper part of the book to be considered north.

The protractor is merely a common rule, folding in two, with a stiff joint, entirely plain, except having scales of paces on its edges. As it is impossible to step yards accurately for any considerable distance, the pace of two feet six inches has been chosen; and the habit of stepping this pace may be soon acquired, by stepping a few times forty paces in a measured distance of 100 feet.

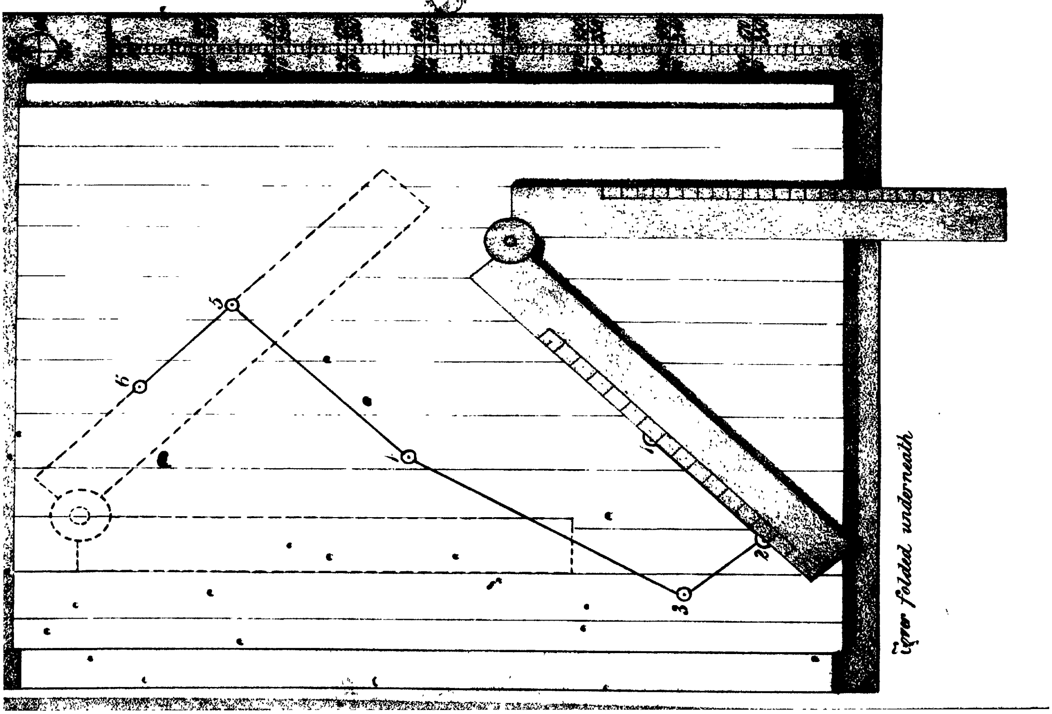
On the edge of the book, a scale of chords, to a radius equal half the length of the rule, is placed, by which the rule may be accurately opened with one hand, in the manner of a pair of compasses, to any angle as far as ninety degrees; and as the outer edges are parallel to the inner, the angle may be plotted by drawing a line against either edge. The scale of chords is figured in such a way that the protractor, by a method that is simple and obvious, is capable of

## STATION POINTER.

3 SALAR JUNG BAHADUR




## FIELD SKETCH BOOK & PROTRACTOR



setting off angles to 360 degrees, though it only extends to ninety degrees. At the top of the scale a little circle is drawn, as a sort of key to the figuring of the scale, and which will prevent all mistake as to the direction of the forward station.

As for general service, it is desirable that all the instruments should, as far as possible, be general in their application: it is an excellence of this method, that all surveys may be plotted, whether made by a compass reading to 90, 180, or 360 degrees.

Suppose I am at station 1, going southward 225 degrees; I open the rule to 225 degrees according to the scale (45 degrees in reality), and slide the *right* side of the rule against the most convenient meridian, until the sloping side touches the station. Now, as I am going south-west, I draw a line in that direction; but if I had been going 45 degrees, or north-east, I should have placed the rule in exactly the same position, only I should have drawn the line in the opposite direction. Again: suppose I have advanced to station 5, and am going north-west to station 6, I open the rule to 315 degrees, and place the *left* side against a meridian, and slide the sloping side to station 5, and draw the line in the direction I am going; but if the forward station had been south-east, or 135 degrees, instead of north-west, this same angle (forty-five degrees in reality) and position of the rule would be proper, only the line must have been drawn accordingly. Hence it is plain that only two positions of the rule are necessary; for by merely placing the rule right or left, and by drawing the line up or down, every angle with the meridian is obtained.

At first it will be better to keep the joint of the rule towards the north, but it may be downwards; and, after practice, a person will use it promiscuously.

In use, the left cover of the book is turned under the other, which gives firmness; and the whole is so light that the hand does not become tired. The surveying compass is not much larger than a watch. It should have a brass loop, through which to pass a ribbon; and when the angle is taken (which is done with one hand) the sights fold down, and the little instrument, being suspended round the neck, may be disposed of like an eye-glass. Hence both hands are free to sketch, having no encumbrance but the book, a little ruler, and pencil. With such means, and especially as the pace is only a good walking step, a large tract of country may be rapidly sketched without exciting notice.

This correct and pleasant method of delineating a few square miles would be so useful to travellers, and might be so easily learned, provided it be skilfully taught, that it is to be regretted the art is not more generally known.

The method of surveying by the prismatic compass appears to be so valuable for military purposes, and the process so well adapted to teach the principles of surveying, that it might, perhaps, be found worth consideration, whether it should not be perfectly understood before a theodolite be put into the hands of a pupil.

SAML. B. HOWLETT,
Chief Draftsman.

63½, Pall Mall,
1st Feb. 1837.

## XI.—*A new Method of Plotting a Survey.* *By* SAMUEL B. HOWLETT, *Chief Draftsman, Ordnance.*

THE circular protractor, at the price of from four to eight guineas, is generally considered the most perfect kind of instrument for plotting the angles of a survey; but against this instrument there are the five following objections:—

It is only steadied by being attached to the paper by pins, and in moving the arms it is liable to shift.

As the vernier has to be set while the protractor is fixed on the paper, and cannot be held to the light, it is next to impossible, in some positions, to see the divisions; or, if the protractor be taken from the paper, time is lost, and error is caused, by having to replace it upon the working meridian.

When the whole set of angles required are set off and numbered, they have to be transferred to the stations, one after the other, with parallel rulers; in doing which much error creeps in, both while setting the edge of the ruler against the points, and then in shifting the ruler along to a distant part of the paper.

It is a very delicate instrument, liable to be soon strained and rendered unfit for use.

Lastly, the general inaccuracy of the method which this instrument implies: for the sources of error are so many, that the work cannot be brought to close in a satisfactory manner, and when done it is little better than a survey plotted by a common protractor, where the degrees and half degrees only are marked.

The old surveyors of the Ordnance used the semicircular protractor, and transferred the instrument itself to the station by means of large parallel rulers fixed to the paper; and having set the arm to the required angle, they drew the line against the arm itself, some inch or two of which was made in a line with the centre and zero. This excellent way was, however, rendered inaccurate by the impossibility of preventing the joints of the large three-bar parallel rulers from becoming loose; and much inconvenience was felt in consequence of the rulers, even at a greater price, not extending sufficiently wide to carry the protractor over a small sheet of plotting cartridge paper.

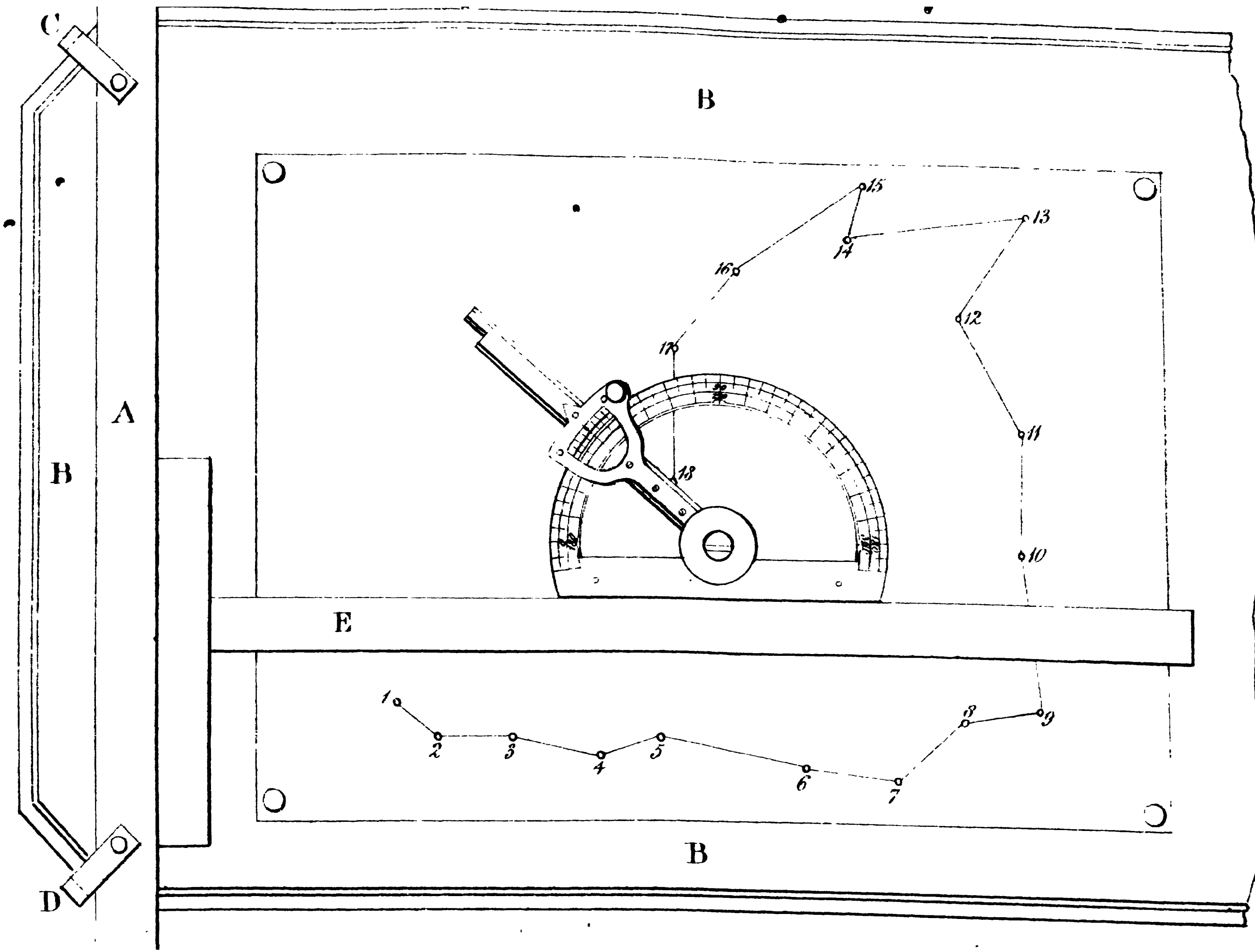
These methods of plotting a survey to a small scale, where an error of ten minutes is not very striking, may answer, and escape censure; but in making surveys of several thousands of acres for content, to a large scale, I have found all the methods above described exceedingly awkward, and not at all adequate to the plotting of the perfect work done by the theodolite. In making surveys of estates and parishes, while on half-pay, I suffered much for want of a better system of plotting than any I could find, after making every inquiry and searching books upon the subject. Such methods as these do not meet the exigencies of practical men, and hence it is usual to employ the chain alone. The theodolite is very little used among private surveyors. They reject the system altogether; and, indeed, may use the chain so skilfully, that under ordinary circumsrances, it leaves nothing better to be desired. The theodolite is, however, an invaluable instrument, and if the proper use of it, together with a more satisfactory method of plottiog, were more generally known among private surveyors, much of this prejudice would certaily give way.

Anxious to discharge the duty confided to me in the most beneficial manner, I have given much study to this as well as other branches of my duty, and have the honour to submit, at least for trial and discussion, the following very cheap and simple means, which is, in all respects, the nearest approach to perfection that I can contrive.

The pattern semicircular protractor, at the price of no more than 2*l*. 15*s*. was contrived and made from my drawing and instructions some few years ago, and must be too well known in the department to need description.

As, when away from home, it seldom happens that the surveyor can obtain a good drawing-board, or even a table, with a good straight edge, I fix a flat ruler, A, to the table, B B B, by means of a pair of clamps, C D, and against this ruler I work the pattern square, E, one side of which has the stock flush with the blade; or if a straight-edged board be at hand, then the square may be turned over, and used against that edge instead of the ruler A. Here then is the most perfect kind of parallel-ruler that art can produce, capable of carrying the protractor over the whole of a sheet of plotting paper of any size, and which may be used upon a table of any form. It is convenient to suppose the north on the left hand, and the upper edge of the blade to represent the meridian of the station.

This protractor is held in the hand while the vernier is set, which is an immense comfort to the sight; and it will be seen that, as both sides of the arm are parallel with the zero and centre, the angle may be drawn on the paper against either side, as the light or other circumstances may render desirable.


C
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From this description, and a mere glance at the plate, it is clear that angles taken with the theodolite, can be transferred to the plot as accurately as the protractor can be set, namely, to a single minute; and that, too, in a rapid and pleasant manner.

By means of the notch at the end of the arm, this instrument may be used in the manner of a circular protractor, should a square not be at hand.

This protractor is specially for plotting a survey, and therefore is figured from left to right; but should it be required for other purposes, to set off an angle from left to right, then mark off the supplement of that angle.

It may be added, that the method of using the T-square against a ruler clamped upon a table, is also exceedingly convenient in making some sort of large unmanageable drawings, in which case the pattern-angle is used for drawing the vertical lines. By this means the T-square may be applied to the making of a drawing of any length; for if a straight line be first ruled along the paper, as a guiding line, the paper may be shifted along under the clamped ruler, and the guiding line set to the square, by which means it may be applied over the whole drawing, let the length be what it may, which cannot be done by the usual method.

SAML. B. HOWLETT,
Chief Draftsman.

83½, Pall Mall,
1st Feb. 1837.

## XII.—*A New Station-Pointer.* *By* Samuel B. Howlett, *Chief Draftsman, Ordnance.*

A B C are ebony, box, or metal arms, working upon one axis, having the edges *abc* radiating from that axis, through the centre of which a hole is drilled to admit a small pin, or protracting needle. The arms are tightened by a thumb-screw on the axis. D E is a box-wood scale of chords to the same radius as the arms A, B, or C, each degree of which is subdivided to twenty minutes.

Suppose it be required to set the instrument to plot a sounding, the left angle, as taken with a sextant, being 44° 5′, and the right 39° 45′. Hold the arm A against the edge of the scale, (which should be kept steady by weights) opposite the 0 on the scale of chords, and open the centre arm, B, until it reach the chord of 44° 5′, and, if necessary, turn the thumb-screw a little; and then, still holding the arm A, place the point of the arm B against 0 of the scale, and extend the arm C to the chord of 39° 45′, leaving the arm B untouched.

The instrument is now ready to be so placed as to coincide with the three points on the chart, representing the station-staves or other objects on shore; and when fitted, prick through the axis with the needle, and the point on the paper will be the place of the boat whence the above angles were taken.

Though this method may seem rough, it will be found that, owing to the length of radius, the instrument may be set with as much real accuracy as can be done by smaller instruments reading to minutes; and then, any little inaccuracy in the position of a sounding ends there, and the error is not continued on from station to station as in a survey.

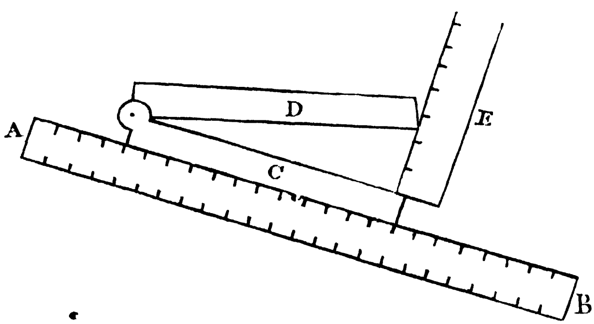
In many cases it is desirable to lay down a few soundings on a map expressly made for military purposes, as well to show approaches by sea as by land; and upon the principle that all maps should be made as complete as possible, especially when intended for general reference, soundings should, when practicable, be given.* For particular services, station-pointers at the price of twelve guineas have been issued; but as this expense forms an impediment in the way of the more general use of this instrument, I have, after many trials, succeeded in making the above, which, at less than a quarter of the expense, will, it is expected, be found even more correct, and certainly more convenient to use, than those upon the usual construction, besides the advantage of being less liable to be put out of order. I venture to submit this instrument, as I am pretty confident, that with nothing better than the pocket sextant to take the angles, and this station-pointer to plot them, many of our maps might be made much more complete and useful.

SAML. B. HOWLETT,
Chief Draftsman.

83½, Pall Mall,
1st Feb. 1837.

## XIII.—*A New Line-Divider and Universal Scale.* *By* Samuel B. Howlett, *Chief Draftsman, Ordnance.*

This simple instrument is for dividing a given space into any number of parts, and for drawing parallel lines, to any scale, with a common drawing pen, more accurately, and in most cases more expeditiously, than can be done by the ruler and compasses.




A B is a box-wood scale, about two feet long, having on its edges, on one side, inches divided into eighths and tenths, and on the other, the foot divided decimally; and C D is a blank two-feet rule, in form like a carpenter's rule, with a stiff joint.

Suppose, for example, it be required to set the rule for dividing any of the divisions on the edge of the scale A B into four equal parts: reduce the one-fourth to a decimal fraction (·25) and it will be the sine of the angle to which the rule must be opened. But the radius of the rule is one foot; and as the foot is decimally divided on the scale A B, commencing from one end, we have only to extend one of the legs, as D, to ·25, taking care that the scale be perpendicular to the other leg, C, as shown by the dotted lines, E, and the rule will be set to the proper angle. Now slide the upper end of the leg C from division to division against either of the edges of the scale A B, and lines drawn against the other leg, D, will be one fourth apart, as compared with the divisions against which the end of the leg C was slid, whether those divisions were inches, halves, quarters, eighths, or tenths.

Hence, to make a scale of forty to the inch, for instance, place the end of leg C against every tenth in one inch, and lines drawn against D, respectively, will divide a quarter of an inch into ten parts; and then draw lines against D every time the end of leg C coincides with the subsequent inches, and the required scale will be drawn.

Suppose it be required to divide a given space into 11·4 parts. Select such divisions on the graduated scale as will be most convenient, which we will suppose to be the inches and tenths. Measure the length of the space to be divided by the same divisions that are intended to be used, or by a diagonal scale of the same terms, and suppose it to be 9·69 inches. Divide 9·69 by 11·4, which gives ·85 for the sine to which the rule must be set by the foot decimal scale. Now slide the leg C along 11·4 inches of the scale, and lines drawn respectively against D will divide the space as was required; namely, a space measuring 9 inches and 69 hundredths, will be beautifully divided into eleven and four tenths parts.

The instrument is here described in its most simple form, adapted for common drawing; but, by adding a few lines on the edge of the leg C, upon the principle of a vernier, lines drawn against D would divide an inch into thousands of parts.

The annexed memorandum, showing how to set the instrument for drawing some of the most common proportions, will more fully exemplify the method, which will be found useful in drawing fortifications, machinery, and various parts of architecture, where fine parallel lines, at given distances, are required.

As far as I am concerned, every thing given in this paper is original. I have, however, since seen in the 'Edinburgh Encyclopedia,' a method of dividing lines by means of a graduated jointed rule, or level; but as that, the present, and the marquois scales, are little more than a mechanical application of the well-known problem for dividing lines, I still feel entitled to submit the present as original, especially as it is the most accurate and universal in its application.

SAML. B. HOWLETT,
Chief Draftsman.

23½, Pall Mall,
1st Feb. 1837.

## MEMORANDUM OF SOME USEFUL DIVISIONS,

### Using the Scales of Inches divided into Eighths and Tenths.

| Required Division. | Sine of Rule. | | Remarks. |
|---|---|---|---|
| 3 inches to a foot | $\frac{6}{12}$ or | ·500 | For these scales twelve half-inch divisions are taken; hence by sliding the rule through that space, against the scale, a foot will be obtained, and each $\frac{1}{2}$ inch will be an inch, each $\frac{1}{4}$ a half inch, and each $\frac{1}{8}$ a quarter. |
| $2\frac{1}{2}$ „ „ | $\frac{5}{12}$ | ·417 | |
| 2 „ „ | $\frac{4}{12}$ | ·333 | |
| $1\frac{1}{2}$ „ „ | $\frac{3}{12}$ | ·250 | |
| 1 „ „ | $\frac{4}{12}$ | ·333 | Here the $\frac{1}{4}$-inch divisions being used, each will be an inch, and each $\frac{1}{8}$ half an inch. |
| $\frac{3}{4}$ „ „ | $\frac{3}{12}$ | ·250 | |
| $\frac{1}{2}$ „ „ | $\frac{4}{12}$ | ·333 | Here the $\frac{1}{8}$-inch divisions being used, each will be an inch, and the half or quarter may be taken by the eye. |
| $\frac{1}{4}$ „ „ | $\frac{2}{12}$ | ·167 | |
| 10 in an inch ...... | $\frac{2}{10}$ | ·200 | Here ten $\frac{1}{2}$-inch divisions being used, each will be a tenth of an inch, each $\frac{1}{4}$ a twentieth, and each $\frac{1}{8}$ a fortieth. |
| | $\frac{4}{10}$ | ·400 | Here the $\frac{1}{4}$-inch divisions being used, each will be a tenth, and each $\frac{1}{8}$ a twentieth. |
| 10 or 100 in an inch . | $\frac{10}{100}$ | ·100 | Here ten inches are taken; hence each inch will be a tenth of an inch, and each tenth a hundredth. |
| 11 in an inch ...... | $\frac{10}{11}$ | ·909 | Hence the $\frac{1}{10}$-inch divisions are used, and each will be the part of an inch required. |
| 12 „ ........ | $\frac{10}{12}$ | ·833 | |
| 13 „ ........ | $\frac{10}{13}$ | ·769 | |
| 14 „ ........ | $\frac{10}{14}$ | ·714 | |
| &c. | &c. | | |

## XIV.—*Account of the Causes which led to the Construction of the Rideau Canal, connecting the Waters of Lake Ontario and the Ottawa; the Nature of the Communication prior to* 1827; *and a Description of the Works by means of which it is converted into a Steam-boat Navigation. By Lieutenant* Frome, *Royal Engineers.*

During the late war with the United States, the communication between the Upper and Lower Provinces of Canada was liable to constant interruption, from its proximity to the American frontier for at least two-thirds of the distance between Montreal and Kingston; which latter town, situated at the eastern extremity of Lake Ontario, and the source of the St. Lawrence, being the principal depôt for naval and military stores intended for the upper province, and containing a large dock-yard, where all the vessels for the defence of the lake are fitted out, becomes in time of war a place of the first importance, and is in fact the key to Upper Canada. Independent of the risk of interruption from an enemy, the difficulty and expense* of moving heavy military stores and ammunition at all seasons along the vile roads by the side of the rapids on the St. Lawrence was excessive; and had the Americans made a more vigorous use of their powers of annoyance, the transport of the two frigates sent out in pieces from England, with all their guns, cables, and ammunition, by this route, would have been quite impossible.

These considerations showed the obvious advantage, and, in the event of another war, the absolute necessity, of some more secure communication with Kingston, which would be beyond the reach of an enemy, and by avoiding any land-carriage or transhipment of stores, would materially diminish the expense of transport. A reference to the map of Upper Canada will show, that the route by the Ottawa and Rideau rivers can alone combine these desiderata; and at the close of the war, in 1814, the attention of Government was turned to this part of the country, of which little was at that time known.

* The cost of the transport of merchandise by the St. Lawrence, from the head of the island of Montreal to Kingston, was in 1815 from 4*l.* to 4*l.* 10*s.* per ton. The Durham boats used for this purpose require six men, and take on an average twelve days in ascending, though only four in returning, and carry about eight tons.

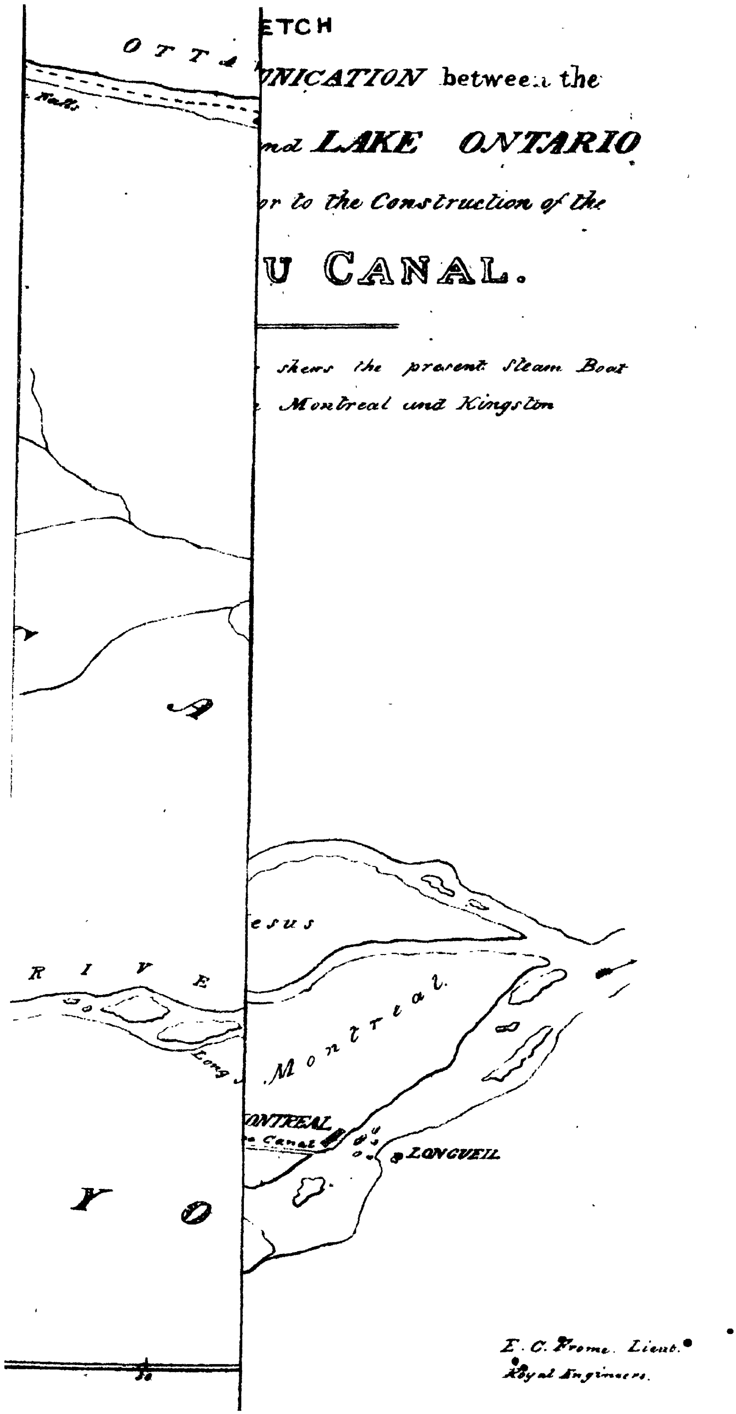
The batteaux also used on the river require fewer hands, and hold about five tons.

In the spring of 1815, Colonel Nicolls, then commanding Engineer in Canada, was directed to send an officer of Engineers to explore and report upon it generally; and Captain (then Lieutenant) Jebb was instructed to proceed upon this duty. His orders were to follow up the course of the Cataroqui from Kingston Mills, and, keeping a northerly direction, to penetrate into the Rideau Lake, and descend the river which flows from it to its confluence with the Ottawa. He was to return up the river as far as the mouth of the Irish Creek, and trace the waters of which it is the outlet to their source, and from thence to follow up the best communication he could find to Kingston Mills, or to Gannanoqui, and suggest any temporary expedients for improving the navigation, so as to render it available for batteaux. He was also directed to note the nature of the country, with a view to its being deemed eligible or otherwise for the establishment of military settlements. Captain Jebb stated on his return, that he considered either of these routes might be rendered practicable, but gave the preference to the shortest by the Irish Creek. The works he proposed were, a dam at the mouth of the Cranberry Marsh, and another where the Gannanoqui leaves the White Fish Lake; the Irish Lake to be deepened by a dam at the mouth of the creek, and the channels of some of the rapids on the Rideau to be cleared. All these suggestions however were of such a nature as he considered would come within the scope of the very limited sum proposed to be expended.

Nothing was undertaken in consequence of this report; but the settlements of Perth, and some years afterwards of Richmond, on two small rivers flowing into the Rideau, were laid out, and the town lots granted mostly to officers and men of regiments disbanded in Canada after the war.

In 1821 the subject was taken up by the provincial government of Upper Canada, who passed an act "to make provision for the improvement of the internal navigation of the province," and appointed commissioners to determine upon the practicability, and report upon the estimated expense, of such undertakings as they might propose; on which they were occupied for nearly four years. The falls of Niagara, and the rapids of the "Long Sault" on the St. Lawrence, being the two principal obstacles to an uninterrupted communication between Lake Erie and the Lower Province, their attention was naturally first turned to these points;* and in 1823 they sent in estimates for a canal to

* The La Chine canal, to avoid the rapids opposite Montreal, was already commenced by the Lower Province, and that at Grenville to turn the "Long Sault" on the Ottawa, by the British Government.



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Royal Engineers.

connect Lake Erie and Burlington Bay, and also a cut between Burlington and Lake Ontario. The following year produced three estimates for canals, of different sized locks and depths of water, connecting Lake Ontario and the Ottawa by the Rideau, and also the Bay of Quinté and Presqu' Ile Harbour; all the details of which were published by the joint committee of the two houses of legislature, to whom the reports were referred in 1825. Previous to this, the Welland canal had been undertaken by a chartered company, leaving only the obstacles on the St. Lawrence to be overcome by improving the navigation of the river itself, or by connecting Lake Ontario and the Ottawa, either by the proposed route of the Rideau; the Mississippi, which joins the Ottawa above the Chaudière Falls; or the Petite Nation, leaving the St. Lawrence a little above Prescott. In a commercial point of view, the first and last of these were considered perhaps preferable, but they would both have been exposed to interruption along the line of the frontier. An estimate was however framed for the improvement of the St. Lawrence as far as the boundary of the Upper Province, and application was made to the provincial government of Lower Canada, to carry the same down to Montreal, and assist in devising some method of avoiding the interference likely to be met with on account of the cession of Barnhart's Island to the Americans. The sum of 5000*l.* which had accumulated during some years from tolls levied on all rafts passing Chateaugay, was recommended by the arbitrators named by the two provinces to be applied to the purposes of this survey. Of the two estimates made by the Upper Province, the first amounted to 176,378*l.* for locks 132 feet by forty, with eight feet water; the second to 92,834*l.* for locks of 100 feet by fifteen, and four feet water.

The estimates for a water communication by the Rideau, were for the following descriptions of canals, by the line of the Rideau Lake, that by the Irish Creek, though the most direct, having been abandoned by Mr. Clowes, the engineer employed by the province, on account of the comparative scarcity of water, and the depth of cutting at the summit level, neither of which objections appear to exist to the extent stated by him.—First estimate, canal seven feet in depth, forty feet in width at the bottom, and sixty-one at the surface of the water, the banks to slope one and a half to one; the locks to be of stone 100 long by 22 wide; cost 230,785*l.* Second, five feet in depth, twenty-eight feet at bottom, and forty-eight on surface; locks of stone eighty feet long by fifteen wide; cost 145,802*l.* Third, four feet water, twenty feet wide at bottom, and thirty-two on the surface; locks of wood seventy-five feet long by ten wide; cost 62,258*l.*

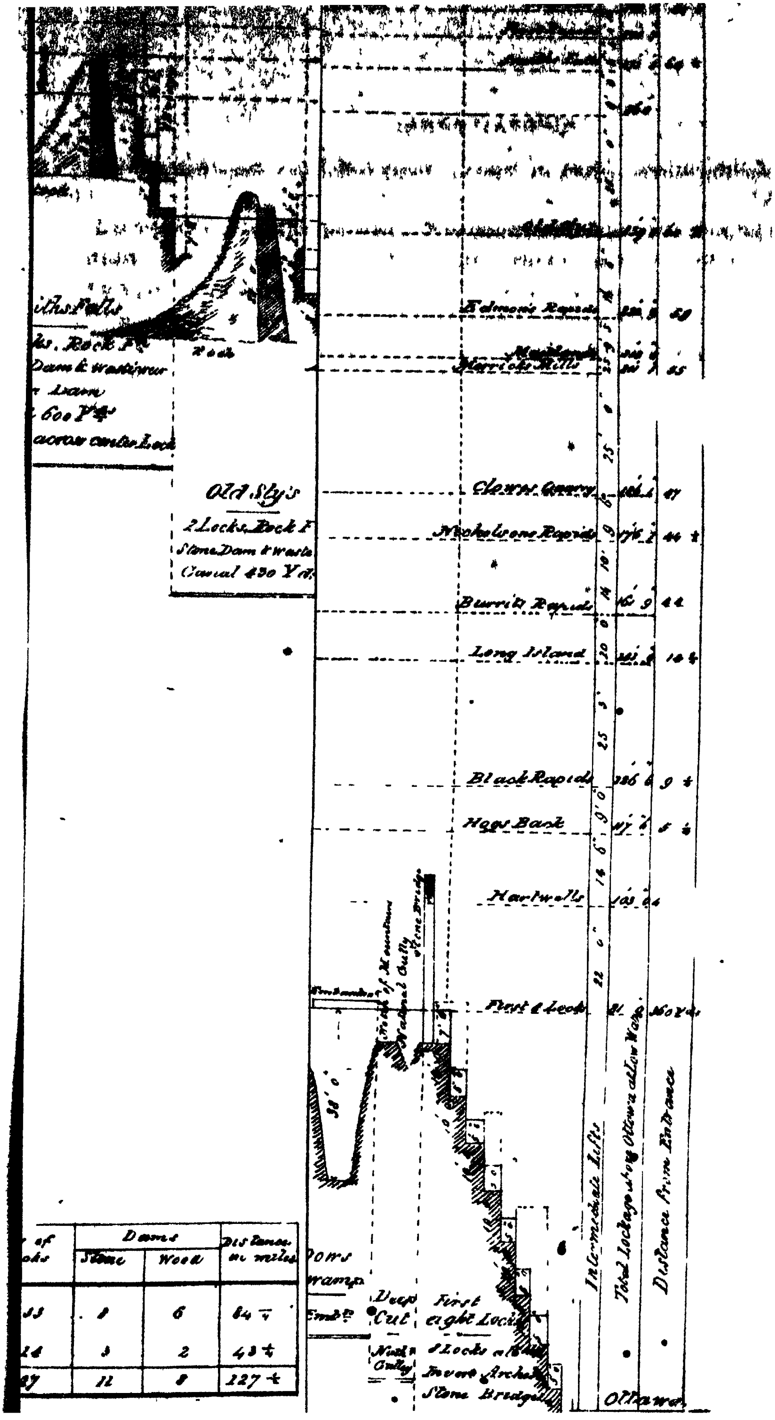
Of these projects the committee appeared to give the preference to the second; but looking forward to the promised loan of 70,000*l.* offered by the British Government (if they did not expect even more substantial assistance), they add in their report, "that if the parent State should assume a share of the charge, it would be highly expedient to attempt a canal of the larger dimensions."

As the circuitous route by which it was proposed to open a secure water communication between the lakes and the lower province, owed its adoption solely to its being considered essential to the future defence of the country, the British Government could not be blind to the advantages of retaining in their own hands the complete control over the work, in case of another war; and in 1825 a committee, consisting of Colonel Sir J. C. Smith, Lieutenant-Colonel Sir G. Hoste, and Major Harris, Royal Engineers, sent out from England to report upon various public works in Canada, were directed to bring home an estimate for the Rideau canal, the locks to be on the same scale as those of La Chine and Grenville, 108 feet long and twenty broad, and the depths of all the necessary excavations five feet.

The amount of this estimate was 169,000*l.*, exceeding the second of Mr. Clowes (on whom they relied for their details and levels) by 20,000*l.*, on account of the increased size of the locks.

In consequence of this report, its construction was determined upon, the expense to be borne wholly by the British Government; and in May 1826, Lieutenant-Colonel By, Royal Engineers, was sent out to superintend the works; the sum of 5000*l.* having been granted him for the first year's expenditure, principally for the purpose of exploring and clearing the country, and obtaining such local information as would enable him to commence operations the moment means were furnished him. His further instructions for the progress of the work could not, from its nature, and the little that was known of the difficulties to be encountered, be very closely defined; but as a general standard for the size and construction of the locks, he was referred to the La Chine canal, and that in progress at Grenville, by the Royal Staff corps; and as at this period it was not contemplated as a steam-boat navigation, towing-paths were to be formed wherever practicable.

Colonel By reached Montreal in June, and, in September 1826, proceeded up the Ottawa to the mouth of the Rideau, where, according to Mr. Clowes' plan, the canal was to join the Ottawa. He however decided upon a deep bay




| …of …cks | Dams Stone | Dams Wood | Distance in miles |
|---|---|---|---|
| 33 | 1 | 6 | 84 ¼ |
| 24 | 3 | 2 | 43 ¼ |
| 87 | 11 | 8 | 127 ½ |

about a mile above the former spot, as better adapted for the entrance; and the excavation for the locks was commenced immediately, as also a series of bridges across the Ottawa at the Chaudière Falls (about half a mile higher up), connecting the two provinces, and opening a communication with a small tract of cleared country at Hull, on the lower Canadian side. Some improvements were likewise made in the timber channel for rafts at these falls; for which service, so totally unconnected with the canal, the sum of 2000*l.* was authorised by Lord Dalhousie to be expended from the military chest.*

The following spring Colonel By took up his residence at the entrance of the canal, which was considered during the execution of the work as head-quarters, and barracks and a hospital were erected there for two companies of sappers, which were sent out from England for this service. The works at the different stations were many of them given out to contractors during the early part of the summer, when Colonel By went through the intended line to Kingston; and in the months of July and August the necessary details were furnished by an officer of Engineers, sent with a party for the purpose, upon which a report and estimate was framed, and sent to England in the autumn of 1827.

The amount of this estimate was 474,000*l.* for a water communication, similar in size and construction of the locks to the La Chine canal, and the work was at once commenced, adhering in many instances to the plan recommended in the report, but in others deviating in part, or even totally from it, as the further development of the ground, when the land became cleared, rendered advisable. It is therefore useless to dwell upon the suggestions contained in it; but before proceeding to any account of the works, as at present finished, it is necessary to describe the nature of the communication as it existed prior to the spring of 1827, omitting all notice of the line by the Irish Creek, which was at once abandoned without meeting with the consideration it deserved, on account of the report given of it by Mr. Clowes.

The river Rideau falls into the Ottawa about sixty miles above the head of the canal at Grenville, over a ledge of rocks more than a mile below the present entrance of the canal. This fall varies from twenty to upwards of thirty feet, according to the season of the year, as the two rivers are

* The largest of the wooden truss bridges, 212 feet span, fell during its construction, just as the string-pieces were placed across the chasm; it was reconstructed and stood till last year, when it again gave way, as well as the smaller one on the same principle. The cause of both failures was the same: the want of proper abutments.

not at their height at the same time, the freshes on the Rideau having subsided, before the principal rise of the Ottawa, occasioned by the melting of the snow in the distant mountains of the north, has commenced. The river for some miles above its junction is almost a continued rapid, and is so obstructed that large canoes frequently made a portage to the *Hog's Back*, a distance of five miles, in preference to poling up the stream. The level of the still water at this place was nearly 115 feet above the Ottawa, and it continued for about four miles to the *Black Rapids*, where was a fall of nine feet in a few hundred yards. Another sheet of still water extended five miles and a half to the foot of *Long Island*, just below which the river Jack, or Goodwood, flowing through the military settlement of Richmond already alluded to, empties itself into the Rideau; and though in the summer the water over the rocks at its junction was hardly six inches deep, in the spring it swelled to a considerable stream, down which a quantity of timber was rafted. The two narrow channels into which this island divided the river were rapids for nearly their whole length of three miles, which generally required (to use the term of the country) a "portage," the whole fall being nearly twenty-five feet. At its foot was a small clearance with a paltry saw-mill on the right bank of the river, but the island and the banks were rocky and uncultivated. From its head was a continued sheet of still water for twenty-three miles, the banks on each side being low, marshy, and totally uncleared, excepting two or three small farms near Garlick's on the left bank, where Stephen's Creek empties itself. Within five or six miles of the end of this sheet of water, is the mouth of the South branch, three miles up which stream was a settlement and mill, known by the name of the owner, "Chetham." For seven miles higher up the Rideau, the country is of a better description, and was settled, about thirty years before the commencement of the canal, principally by emigrants from the United States. In this distance the following impediments were met with in the river: "*Burritt's Rapids*" and *Hurd's Shallows*, immediately above the still water, at each of which a wooden bridge crossed the river; *Nicholson's Rapids* two miles higher, and *Merrick's Rapids* and *Falls*: the total rise by all these being nearly sixty feet. At the last named place a rough dam had been formed across the river, with a grist and saw-mill. There was a tolerable road to Brockville, distant thirty-two miles, and another to Prescott five miles nearer. The clearance terminated half a mile above this dam, and another eight miles of still water, with low swampy banks, extended to *Maitland's Rapids*, where a road from Brockville crossed the river by a ford.* Another interval of still water, for four miles, to *Edmons'*, was succeeded by a series of small rapids for nearly two miles, to *Old Slys*, and about a mile higher up, the river rushed down a descent of about thirty-five feet in a few hundred yards, over a rough mass of limestone rock. The channel was not much above fifty feet wide, and advantage had been taken of this fall to establish a saw-mill and dam by a settler, from whom the place received its name of *Smith's Falls*, but there was no clearance of any size. For nearly three miles above this mill, a series of small rapids extended to what was termed the *First Rapids* on the Rideau. A stream called Owl Creek entered the river at the lower end of this distance, and Cockburn Creek just above the first rapids; the latter has its source near the Mississippi river, and may hereafter be the means of connecting its waters with the Rideau canal.

The entrance to the *Rideau Lake* may be said to commence two or three miles above this creek, and about another mile further up, the river Tay empties itself into the lake. The town of Perth, the largest of the two military settlements, is situated on this river, eleven miles from its mouth, and its inhabitants have, since the commencement of the Rideau canal, formed a navigation for small steam-boats as high as the town, by a series of dams and locks at the different rapids.

The direction of the length of the Rideau Lake is nearly south-west, and the distance from the first rapids on the Rideau, to the isthmus where the line of canal leaves the lake, is twenty-three miles. At *Oliver's Ferry*, where the road from Brockville to Perth crosses, it contracts to 400 yards, and opens out again in a deep bay to the eastward, making the extreme breadth of the lake, which is full of small islands, about seven miles. At the *Upper Narrows* it was again contracted to a channel of not more than 100 feet, by a narrow low tongue of land which projected from the north-western shore, and has been since cut through. This channel was three miles from the *Isthmus*, between the Rideau and Mud Lakes, where canoes (the only mode of conveyance that can be used on the small rivers and isolated lakes of Canada) were obliged to make a "portage" of a mile and a half. The level of the *Mud Lake* was three feet and a half below that of the Rideau, and its shores were rocky and uncleared. Crossing it in the direction shown in the sketch, a narrow passage, through bold rocks of granite, led into *Clear Lake*, between which and *Indian Lake*, a strip of land

* A mile and a half below this is the mouth of the Irish Creek, once proposed as the line of the intended communication; and about the same distance, still lower, a large stream, called Barber's Creek, enters the Rideau, both on the right hand.

about 180 feet broad, required another portage. A winding creek led from this to *Chaffey's Mills*, where a dam had been formed to obtain a head of water to work a saw-mill and distillery, to supply the few scattered settlements in the neighbourhood: the shores of all these lakes being uncleared, and, from the rocky nature of the soil, of little value. The fall at the mill-dam was about thirteen feet, and its distance from the entrance into Mud Lake was five miles. Following the creek below the dam, and keeping the eastern shore of a small lake (called *Musquito*, or *Opinicon*) led into another channel, where was also a wooden dam and saw-mill, with a fall of about seven feet and a half, belonging to a settler of the name of Davis. The outlet of the small lake below this (*Sand Lake*) was through a narrow crooked ravine, with high rocky banks of sandstone and a species of granite. By this channel the waters of these lakes emptied themselves into *Cranberry Lake*, falling about sixty feet in a distance of less than a mile. For ten miles below this, the route continued through the lake, and by a channel through a quantity of marshy land which had been flooded by dams erected at the *White Fish Falls*, and at the *Round Tail*, the source of the *Cataroqui*.*

A portage was made round this dam, where was a fall of five feet, and another a mile below, where an establishment, consisting of saw and grist-mills, had been erected by a Mr. Brewer, with a fall of water of eleven feet. The banks, on first entering this river, were rocky and precipitous, but they rapidly changed their character after leaving *Brewer's Upper Mills*. Two miles below was another dam and mill, belonging to the same individual, with a head about eleven feet. Two small rapids only occurred between this place and Kingston Mills, which in the spring were hardly discernible, the narrow sluggish stream winding its tortuous course between clay banks not more than three or four feet above its surface, and occasionally passing large swamps with a quantity of dead timber standing on the flooded land; its breadth did not average more than sixty feet, and though generally deep enough for boats, particularly in the spring, at the end of summer it was in many places too shallow even for loaded canoes.

At *Kingston Mills* a saw-mill had been erected, at the expense of Government, with a rough sort of dam abutting upon the granite rocks, which here contracted

* The creek across which this dam was erected, leads into the White Fish Lake, from whence flows the river Gannanoqui, entering the St. Lawrence about eighteen miles below Kingston.

the channel. The fall from the mill-pond was about twenty-six feet, into the head of a deeply-indented bay of Lake Ontario, about five miles from the town of Kingston. This bay, generally known by the name of Cataroqui, was nearly choked up with sedgy islands, between which a channel was kept clear by the stream, but about a mile from the mill-dam a rocky bar crossed it, on which there was sometimes not more than three feet of water.

From this description of the chain of lakes and the rivers that were to form this communication, it appears obvious that the general features of any work, to render them navigable, must consist of a series of dams and locks at each obstruction, raising the water at the foot of each rapid to the level of that above, where practicable, and locking by the side of the dam. The excavation necessary for canals in a cultivated country is thus saved, and the rivers and lakes converted, from a succession of falls and rapids, into steps of still water at different levels. This was the view taken by Lieutenant-Colonel By, and acted upon by him perhaps in excess; and the same plan was also adopted, though not to the same extent, by Mr. Clowes, the engineer, previously employed by the province. Canals in a country where water is of value and scarce, are of course entirely different in their principle from those suited to Canada; where the only difficulty consists in attaining a complete control over the immense quantity of water passing through a great extent of partially explored country, particularly during the melting of the snow and ice in the spring.

The enlargement of the locks from their original plan was authorised by the committee, consisting of Sir J. Kempt (then Lieutenant-Governor of Nova Scotia), and Colonels Fanshawe and Lewis, Royal Engineers, who were ordered, in the spring of 1828, to examine into the details of the Rideau canal on the spot, and decide upon several alterations which had been suggested, and referred to a committee of Engineer Officers in Pall-Mall, of which the late Sir A. Bryce was President, in January 1828. Such portions as were necessary of those which had been commenced on the smaller scale were pulled down, the contractor being paid for the work done by measurement, and afterwards allowed the materials for the trouble and expense of removing them.

The following extract from their Report shows the general state in which they found the existing navigation of the Ottawa and Rideau between Montreal and Kingston.

"This line may be divided into two portions: 128 miles from Montreal by the Ottawa to By-Town at the entrance of the Rideau; and 154 miles by the Rideau river and lake navigation from By-Town to Kingston.

" The first commences with the La Chine canal at Montreal, extending nine miles, and is complete for vessels not exceeding twenty-feet beam, and five feet depth of water. This is a provincial work.

" At the junction of the Ottawa and St. Lawrence, at the western extremity of Montreal Island, are St. Ann's Rapids and Vaudreuil Passage, separated by the Isle de Perrot, and not navigable for vessels of the above draft in dry seasons. But from hence, for a distance of twenty-seven miles to the foot of Carillon Rapids, such vessels may be used. The Carillon Rapids are not navigable, and will require a canal one mile and a half long with two locks.

" The Chûte à Blondeau is a short rapid, intermediate between the Carillon and Grenville, which will also require a canal and one lock. At the foot of the Long Sault of the Ottawa, commences the Grenville canal, now executing by the Royal Staff corps, originally intended for vessels of twenty-feet beam, and four-feet draft of water, but will admit of six-feet water. Three out of the six locks intended for the Grenville canal, and nearly all its excavations, are completed. This distance of interrupted navigation, from the foot of the Carillon to the head of the Long Sault, is about twelve miles; from hence to the entrance of the Rideau navigation is a distance of forty-four miles, having occasional shoals, with not more than five-feet water in dry seasons."

The progress then made in the Rideau navigation is next dwelt upon, but it is unnecessary to allude to it here.

The Carillon, Chûte à Blondeau, and Grenville canals have since been completed, and such of the locks as were not finished, or nearly so at this period, have been built of the enlarged size; the others have not been altered, and prevent the steam-boats which ply on the Rideau from passing through the Grenville canal.

The whole chain of communication between Montreal and Lake Erie is now accomplished by seven canals, of which the Rideau is but one section. They have been already alluded to, but are given below in the order in which they occur.

1st. The Welland canal, uniting Lakes Erie and Ontario.

2nd. The Rideau, connecting the waters of Lake Ontario and the Ottawa.

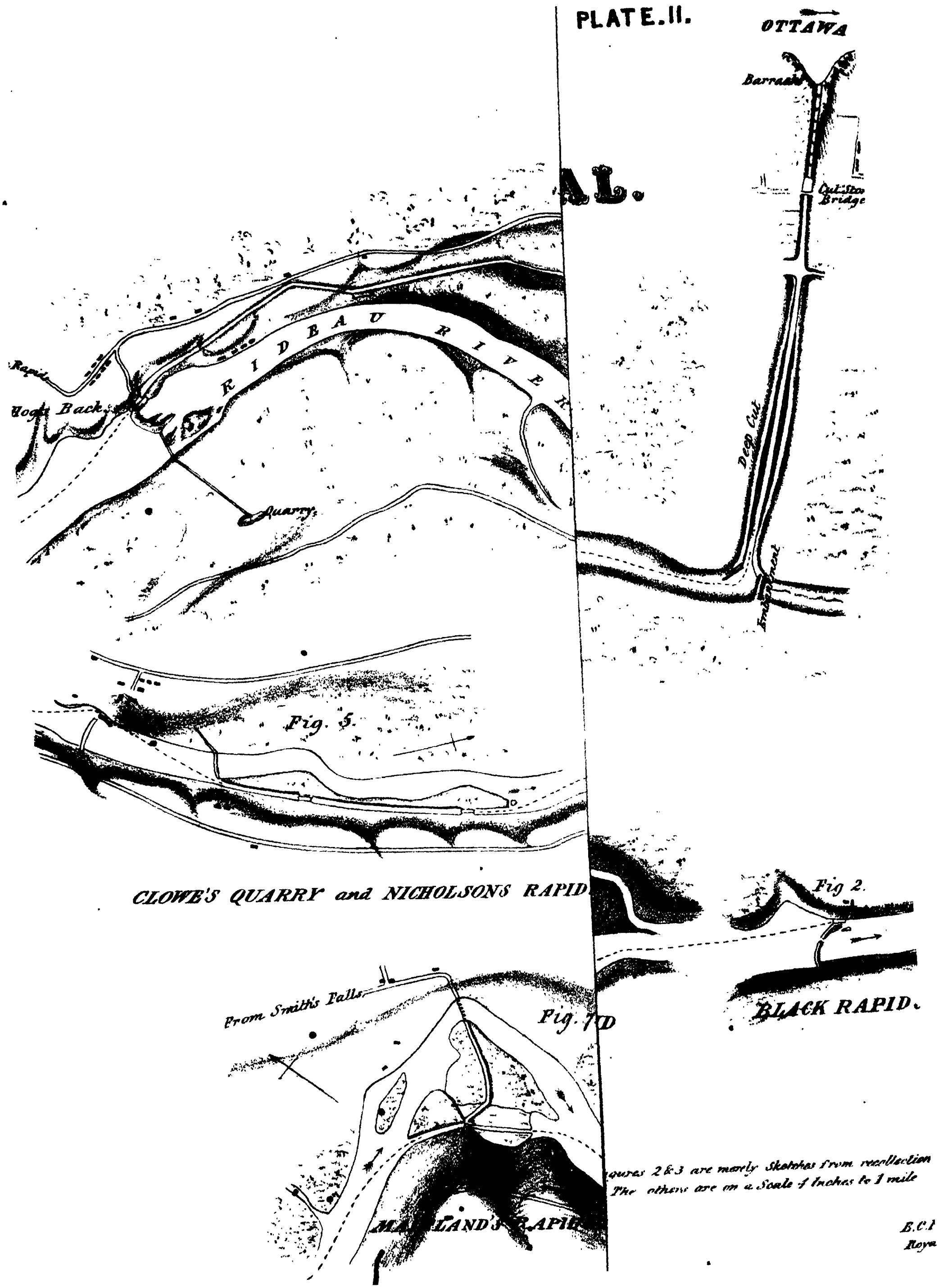


PLATE. II.
OTTAWA
Barracks
Cut Stone Bridge
AL.
Deep Cut
Embankment
Rapids
Hogs Back
RIDEAU RIVER
Quarry
Fig. 5.
CLOWE'S QUARRY and NICHOLSONS RAPID
Fig 2.
BLACK RAPID.
From Smith's Falls
Fig. 7
MAITLAND'S RAPID
igures 2 & 3 are merely Sketches from recollection
The others are on a Scale 4 Inches to 1 mile
E.C.
Roya

3rd. The Grenville canal, turning the rapids of the "Long Sault" on the Ottawa.

4th. The Chûte à Blondeau, consisting of a single lock and canal, less than a mile long.

5th. The Carillon, of two locks and a canal, about two miles and a half long. The three last are generally known as the "Ottawa Canals," the distance, from the head of the Grenville to the foot of the Carillon, being about twelve miles. They were all constructed by the Royal Staff corps, and were commenced in 1821, and finished in 1834.

6th. A single lock at the "Vaudreuil" passage, thirty miles below the Carillon, built by and in possession of a private company.

7th. The La Chine canal, extending nine miles from the head of the rapids to the town of Montreal. This is a provincial work, but the Government have a right to a free passage for all stores and troops, having advanced 12,000*l.* during its construction on that condition.

When the projected canal at St. Ann's is constructed, the lock at the Vaudreuil Passage will become useless; and should the rapids on the channel at the back of the island of Montreal be hereafter rendered navigable, the communication will be unbroken between the Atlantic and the Upper Lakes. At present it is interrupted at Montreal, and the interests of the merchants of that town are of course opposed to any plan by which it would be avoided.

The accompanying map shows, by the dotted line, the present route for steam-boats between Montreal and Kingston.

*Plate 2, fig.* 1.—To return to the subject of the works by which the part of this route between the Ottawa and Lake Ontario has been converted into a steam-boat navigation. At the entrance from the Ottawa, eight locks, built on invert arches, are placed in succession, the breastwork of the river lock (allowing seven feet water over the floor) being eleven feet high, and each of the others ten feet. There being also seven feet on the upper sill of the upper lock, the total lift is eighty-one feet from the surface of the average lowest water in the Ottawa. The soil in which the lock-pits were excavated is rather a stiff clay, mixed with a few boulders, and loose veins of sand were met with near the centre. Immediately above the locks, the canal for a short distance is cut through rock. The material of which the locks are built is a compact limestone, and was quarried on the cliffs on each side of the excavation. Nearly the same species of stone is used for all the locks as far as the Rideau Lake. Two large stone buildings were erected at an early stage of the work on each side of the locks for a commissariat store and Engineer office; and barracks and a hospital, on the hill above the entrance, for the two companies of sappers, who were for the first summer encamped on the opposite height, the country being at that time a perfect wilderness. Workshops were also built on a large scale, in which the artificers from the sappers were employed on the lock-gates, &c. as well as a number of civil carpenters and blacksmiths; and a large rambling village soon sprung up at this spot, containing a number of stores to supply the wants of the men employed at the works immediately in the neighbourhood. A stone bridge crosses the canal above the upper lock, and connects the buildings on each side of it.

These locks were among the first that were tried, and the water forced its way through the breastworks; in many instances moving the large stones which formed the sills. These were afterwards secured with a number of fox-wedge bolts, five or six feet long, and heavy iron straps connecting them at the angle. A quantity of cement, of which none had been used in building, was forced into the breasts, side-walls, and floors, in the shape of grout, by means of long tin tubes; and being allowed time to consolidate, it has rendered them nearly water-tight. This same expedient has been followed in almost all the works, particularly those which were not founded on rock, and has every where been found to answer. The cement was made from a stone quarried on the opposite side of the Ottawa, which, being burnt and ground very fine, proved a better water-cement than some obtained from the States, and far superior to the Harwich cement, which was nearly spoiled before it reached the canal.

Above the head of the first eight locks is a basin surrounded with an earthen embankment, from whence a channel is cut, with a pair of floodgates at its entrance, by means of which the canal may be drained. The *deep cut* extends in the same line as the locks, running east for three quarters of a mile, till it enters a natural ravine, whose course is about north and south, the average cutting being twenty-five feet. The soil is a stiff clay, but which is very soluble in water, and occasioned considerable trouble and expense in excavating, having slid more than once "en masse" into the canal.

An embankment across the northern end of this ravine where it meets the deep cut, retains more than the required depth of water for nearly two miles to the *Notch of the Mountain*, where the cutting recommences, and continues, at an average depth of twenty feet, through gravel and boulders for half a mile, to *Dow's Great Swamp*, which by means of two massive earthen embankments, is converted into a pool twenty feet deep.

About seven hundred yards more excavation through a swamp, at the average depth of three feet, brings the canal to *Hartwells*, where are two combined locks built of limestone upon invert arches, on a foundation of clay mixed with large boulders, and full of springs. Blocks of rough stone were thrown in between these boulders, and the masonry of the locks built upon them, no piles having been used. In t' wing of the upper lock a small regulating sluice is constructed, capal.. of emptying the canal above if required, part of its floor, which is of wood, being one foot below the level of the bottom. An immense quantity of cement grout was forced into the masonry, principally of the invert arches; holes being drilled into the work at intervals, and the short end of the bent tube inserted some inches, and well seamed with clay. A large funnel was formed at the other end, and the liquid grout poured in had thus a pressure of twelve or fifteen feet, according to the length of the tube.

Between this work and the *Hog's Back* is one mile of cutting, running on the slope of the left bank of the Rideau for nearly half the distance. Below the locks at both places, the steep slopes were reveted with rough stone, to prevent their being injured by the rush of water from the sluices.

At the *Hog's Back*, a little more than four miles from the entrance, the canal first enters the Rideau on its left bank. Of the two combined locks constructed here, the upper is only a guard-lock, its coping being eight feet above the surface of the seven-feet water on its sill; the lift of the other is fourteen feet six inches, allowing six feet in the lock; and the height of the masonry of the breast is thirteen feet six inches. The stone used in building was quarried on the opposite side of the river, and is very similar to that at the works below: the excavation was also clay mixed with boulders, and the walls and invert arches were built upon large rough stones without any piling. The recesses were planked.

The dam, one end of which abuts against the wing-wall and backing of the upper lock, was intended to have been of the construction originally proposed in the general specification; the masonry of large stones placed on edge, each alternate one of different height, so as to break joint, with a thickness of puddle behind this wall, and the remainder of the mass and the slope up-stream of clay and rubbish; the water flowing over the top. The first attempt made by the contractor was destroyed early in the spring of 1828, after the arched key-work (as the curved masonry was called) had been partially raised to the height of thirty-seven feet, by the water turning the flank of the dam on the side of the locks, and carrying away a large mass of the clay bank on which it abutted. Soon after this, the contractor gave up the work; and the two companies of sappers, with some hundred labourers, were employed upon it all the winter of 1828 and 1829. The masonry was nearly completed, more than twenty-five feet thick at the base, before the breaking up of the frost; but on the 6th of April, the water, forcing its way through the mass of frozen earth which had taken all the winter to accumulate, made an enormous breach near the centre of the dam, carrying away "en masse" every thing opposed to it. It was afterwards finished under the superintendence of Captain Victor, Royal Engineers, by forming a strong framework of timber in front of the beach, which was afterwards filled with stone, and supported in the rear by a quantity of large stones thrown in from the top, and filled in front with an enormous mass of clay, stone, and gravel; the base, extending about 250 feet up the stream, forming a slope of about five to one. It is now one of the most substantial works on the whole line of the canal.

Luckily the rock, which on the left bank of the river (where the locks are placed) only rose twelve or fourteen feet above the bottom, on the opposite side was nearly forty feet, and made an excellent floor for the channel cut to carry off the surplus water. The waste weir is framed of timber, strongly bolted to the rock, and backed with large blocks of stone. In spring-floods this helps to carry off the rush of water, but the main channel is sufficient of itself at other times. The top of the dam is on the same level with the coping of the lock, eight feet above the average surface-water. It forms a sheet of still-water to the foot of the works at *Black Rapids*, a distance of four miles.

*Plate* 2, *fig*. 2.—This work consists of a single lock on the left bank of the river, built on a rock foundation, and a dam about twelve feet high, constructed on the original plan, with the water flowing over it; but, to avoid the injury likely to be sustained by the large volume in the spring, a cut-stone sluice-way was formed on the bed of the river, between the wing-wall of the lock and the dam, closed as required with squared logs lowered down a groove in the piers of the masonry. Even the small quantity of water that passed over the dam after this sluice was constructed, carrying a mass of floating timber down with it, caused considerable injury to the rock-foundation upon which it was built, and to the dam itself. The lift of the lock is nine feet, allowing seven feet water on the lower, and six feet on the upper sill. The height of the breastwork being ten feet deep.

*Plate* 2, *fig*. 3.—At the foot of *Long Island*, five miles and a half higher up, are three combined locks on the right bank of the river, on a rock foundation, and a dam thirty-one feet, on the original plan; but from the damage done at the work below, by allowing part of the water to flow over a height of only twelve feet, it was not deemed prudent to try the experiment here; and a large channel was cut through the clay, on the opposite side of the river to a ravine, through which the surplus water finds its way back into the river about a quarter of a mile below. The dam was raised four feet, to guard against the spring-floods, and an embankment between it and the sluice-way continued on the same level. This sluice-way consisted of three channels of thirty-three feet wide, between piers of cut stone sixty feet long, the centre about six feet deeper than the two extreme ones. The floors were of timber, continued for some distance below the end of the piers; but where this flooring ceased, the water formed deep pools, undermining the whole work, which has since been totally destroyed, and a year ago a new sluice-way was constructed on a better principle. Another channel, to carry off a portion of the water, was also formed by taking advantage of a creek a mile and a half up the river, and leading it into the same ravine. The total lift of the three locks is twenty-five feet three inches, allowing eight feet five inches water in the lower lock, and seven feet against the upper gates.

*Plate* 2, *fig*. 4.—At *Burritt's Rapids* (twenty-five miles and three quarters above) is a single lock and dam; the former built on the right bank of the river on a very stiff clay foundation, with a wooden floor; the lift is ten feet, seven feet depth of water being on the upper sill, and nine feet in the lock, the bottom of which is at least three feet lower than a rocky shoal in the bed of the river a short distance below. The canal above is about a mile and a quarter in length; and advantage having been taken of a hollow into which water always flowed in the spring, the cutting was not deep, but near the lock the embankment is considerable. A permanent wooden bridge crosses the canal, about 900 yards above the lock, where a road led to a bridge across the river. The lower string-pieces are twenty-eight feet above the surface-water, to allow a sufficient height for the chimneys of steam-boats. The upper sill of the lock is one foot two inches lower than the floor of that of the work above; but the canal is not excavated quite so deep, part of it being through rock. The dam could not be constructed at the foot of the small rapids, on account of the flat country on the opposite shore, but is situated within less than 400 yards of the head of the canal: it is formed of timber framed and bolted to the smooth rock, and the intervals between the bays are filled up with pine-logs squared at three sides to fit the uprights, and to be nearly water-tight when laid one upon another. The upper row can be removed, to prevent any great rise of water in the spring, and several whole bays taken up if necessary. The average height is about eight feet, and the length between eighty and ninety yards, each end abutting upon a cut-stone pier.

*Plate* 2, *fig.* 5.—At the next work, *Nicholson's Rapids*, distant one mile and three quarters, five feet ten inches water is backed up by this dam into the lower lock, which is situated within 200 yards of the river; a canal nearly 400 yards long intervenes between it and the other lock, with a rough stone embankment backed with clay on the river side, the other cutting into rather a steep bank. Above this a similar canal extends about the same distance till it enters the river, the excavation being altogether 1120 yards long, and entirely through rock, except a small portion near the river below. Close to the head of the canal a regulating sluice-way of timber, between rough stone piers, is formed in an opening cut through the rocky bank to the river, to prevent any very large body of water flowing over the dam, which is formed on a plan something similar to that at Black Rapids, but instead of clay, the slope up-stream consists almost entirely of gravel and broken stones: the section is much diminished by this change, and there is no risk of its washing away, and the puddle sinking at the back of the key-work; the height averages about nine feet, and to prevent the rock being worn away by the fall of water, two steps of large rough stones are laid to break its fall. The lift by these two locks, which are founded on remarkably level beds of limestone, is fourteen feet ten inches, seven feet six inches by the upper, and seven feet four inches by the lower, reckoning upon five feet six inches water in the canal above. Their breastworks are seven feet and eight feet two inches.

On entering the river, boats cross to the opposite side, where the next lock is entered only 300 yards above. It would have been a far better plan to have kept the right bank, and built the lock there, but it was nearly finished before the lower work was laid out, which had to be altered, from its original impracticable plan of a single lock and dam, on account of an error in the levels.

*Plate* 2, *fig.* 5.—The lock at this place, "*Clowes' Quarry*," has no breastwork, the whole lift of nine feet six inches being thrown on the upper gates, and the coping of the walls having a height of five feet eight inches over the surface-water. The excavation for the lock-pit, and the short cut of about 130 yards below it, was through a loose shelly limestone, which forms the floor of the lock; both the sills are of wood, bolted to the rock, and nearly on the same level. The grooves in the upper-wing walls are filled up with stop-gate logs permanently wedged in to a height that allows between five and six feet water over them; and the few inches interval between them and the broken face of the rock that was excavated for the breast, filled up with small stones laid in cement. The dam is about fifteen feet high, has 300 water-way (the wings being raised to the level of the coping of the lock), and was commenced on the original plan, but the puddle which washed through the stones and left the key-work in many places bare for a depth of several feet, was replaced with broken stone. Between the dam and lock, a cut-stone regulating sluice, with grooves for squared logs, is formed similar to that at the Black Rapids, the piers being founded on the rock forming the bed of the river, and raised as high as the coping of the lock, but its direction is turned towards the centre of the curve of the dam, to save the backing of the lock from injury. Two steps of large stone are laid close to the base of the key-work of the dam, to save the rock, which was considerably worn the first spring that the water was allowed to flow over.

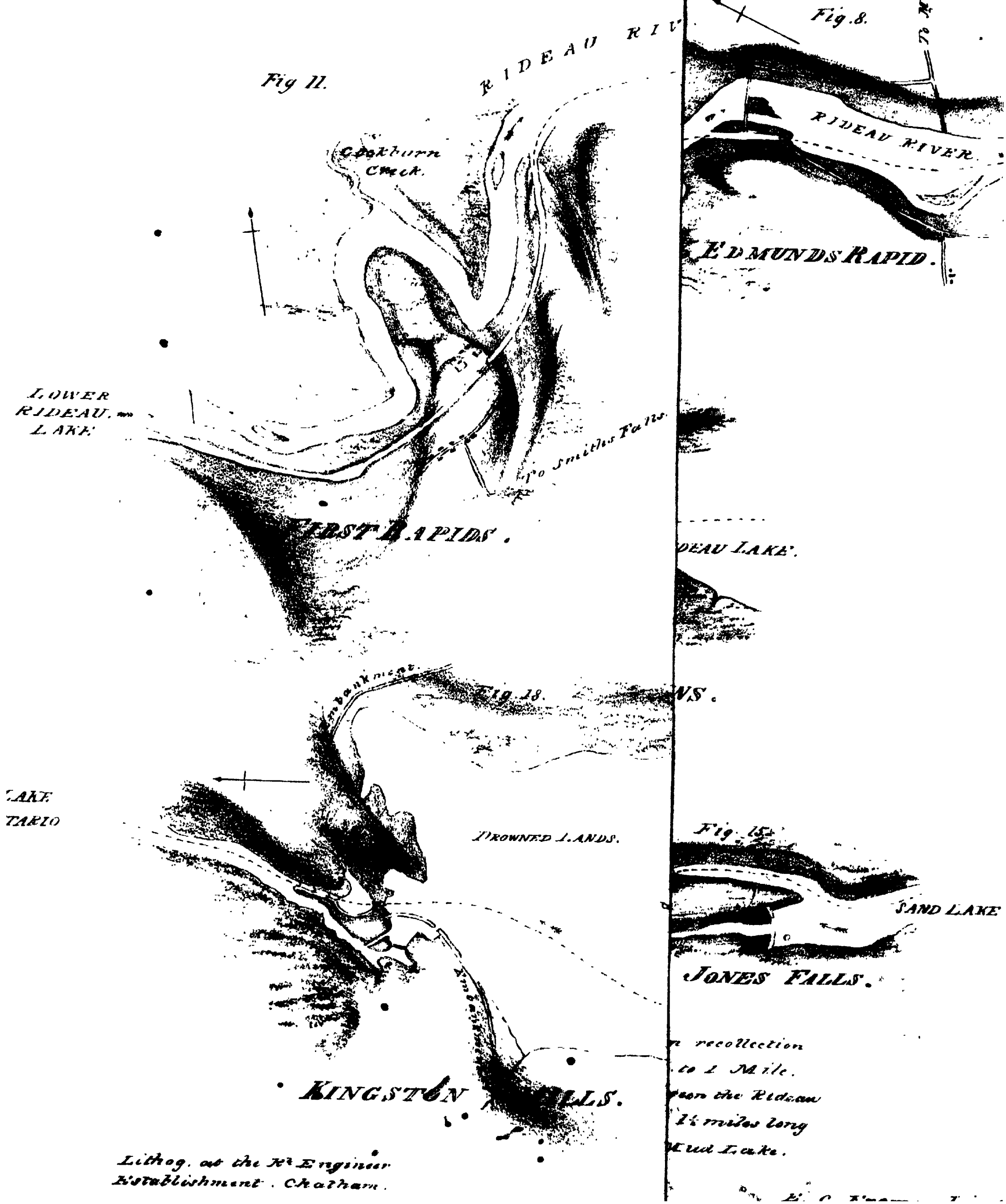
*Plate* 2, *fig*. 6.—At the old settlement of *Merrick's Mills*, two miles and a half higher up, the works are all on the right bank of the river, and are totally different from those first proposed, where the locks were to have been built in a channel which had been cut round the old saw-mill dam for rafting timber. The embankment necessary at the head of the locks, had this project been attempted, would have been a much more serious undertaking than was anticipated when the estimate was made in 1827.

The three locks are now all detached, the lowest, into which seven feet three inches is backed by the dam below, being within 150 yards of the river. The excavation, excepting this distance, is mostly through a shelly sort of limestone, and would average about the depth necessary for the canal; the gradual slope of the land allowing the locks to be placed so as to balance the necessary embankment and cutting. Basins are formed between the centre lock and those above and below it, the walls consisting of rough coursed stone laid in mortar, with a backing of clay-puddle, retained on the river side by a dry wall, and a slope of stone and clay from the excavation. The combined lifts of the locks amount to twenty-five feet, the rock forming excellent floors. Over the lower piers of the upper lock is a rolling bridge, where the road from Brockville crosses, and continues over the river on the top of Merrick's old dam. A large block-house is built just above this bridge, and close to the lock, of fifty feet square, the lower story of rough coursed masonry, and the upper of timber, projecting over the basement: it is used as a house for the lock-master and assistants. The total length of the canal is 1050 yards; and from a little above the head of the upper lock is an embankment two or three feet high, on the edge of the excavation, on the river side, to guard against the rise in spring-floods. The dam crosses the river a little below the entrance of the canal, and is connected with the embankment by a substantial rough stone wall, with a slope of gravel and broken stone in front. It is of wood, similar to that at Burritt's Rapids, and varying from six to ten feet high, as the rock dips across the river. The logs across several bays are constructed to be easily lifted, and the whole of the upper tier can also be removed if necessary. In front is a slope of gravel, and two or three steps of large stones, laid with care behind the wood-work, break the fall of water, and protect the bed of the river.

At this place, now called Merricksville, there has sprung up, since the commencement of the work, a rather large village, and the roads to the frontier have been much improved. The whole clearance from Burritt's Rapids is known by the name of the "Lower Rideau Settlement;" and after passing through the "Bush," about four miles on the road to Brockville, another clearance extends westward on a ridge of land to Maitland's Rapids, called the "Upper Rideau:" these were both settled principally by emigrants from the States.

*Plate* 2, *fig*. 7.—At *Maitland's Rapids*, a mile and a half above the mouth of the Irish Creek, and eight miles above the locks at Merrick's, a canal of about 450 yards in length is cut across a low swampy tongue of land, on the right bank of the river, at the extremity of which is a wooden dam, similar in construction to that described above. Its height is about seven feet, and an earthen embankment, nearly 400 yards in length, in which is a wooden regulating sluice, connects it with the wing-wall of the lock, which is crossed by a rolling bridge; the road from Brockville continuing on the top of this embankment, to a ford below the dam, which however is sometimes almost impassable, from the water backed up. The lock is situated nearly in the centre of the canal, and has a lift of only two feet three inches thrown on the upper gate, there being no masonry breastwork: both sills are of wood, bolted to the rock bottom, and the depth in the canal, above and below, is five feet six inches. An extensive swamp, crossed by a "corduroy bridge," about a mile to the southward, threatened to afford a new channel to the river when raised by the dam, and an embankment

PLATE. III.




Lithog. at the Rl. Engineer Establishment. Chatham.

has consequently been formed across it, at the narrowest point that could be found.

*Plate 3, fig.* 8.—Four miles above is another single lock and dam, at *Edmons' Rapids*, also on the right bank. The lock is built close to the river, on a stiff clay foundation, the floor being composed of thick pine-plank, laid lengthwise, on sleepers which extend under the lock walls. The sill not being far advanced when the failure of the first trials at the entrance locks occurred, was laid in cement, as was also the case at nearly all the works up from Burritt's Rapids, and the stones notched to the course below. The canal, above the lock to its entrance into the river, is 215 yards, the excavation being all a very stiff clay mixed with boulders. The dam, which crosses the river forty yards above the wing-wall of the lock, is of stone laid on edge, founded on the rocky bed of the river, and instead of clay puddle at the back of the wall, the whole mass consists of broken stone and gravel. A cut-stone regulating sluice is formed in the right channel of the river, which was formerly separated by a small island, now crossed by the dam. Its height is about thirteen feet, and length of water-way 315 feet; an earthen embankment extends from the end to the wing-wall of the lock, being raised, as well as the abutments of the dam, above the level of the highest spring-floods. The lift of the lock is eight feet eight inches, allowing seven-feet water below, and five feet six inches on the upper sill, making the height of the masonry of the breast ten feet two inches above the wooden floor.

*Plate 3, fig.* 9.—At "*Old Sly Rapids,*" one mile and three quarters distant, are two combined locks on the left bank of the river, founded on rock; the walls on the river side are built of an extra thickness of three feet of masonry, and faced with ashlar, instead of having any backing of earth behind them. The total lift is sixteen feet six inches, allowing five feet six inches water below, and seven feet on the upper sill. Both the stone sills were laid in cement, as at Edmons'. The rock floor of the upper lock having been much shaken by the blasting during the excavation, pieces of timber were shaped to fit the rock between the piers, and bolted to it. The dam, about 250 yards long, abutting on the wing-wall and pier of the upper lock, was constructed on the original plan on which it was commenced, but was raised, to prevent any water flowing over it, and a channel sixty feet wide cut through the rock, on the opposite side of the river, to the level of the bottom of the required navigation, in which was placed a wooden waste-weir with moveable logs as a regulating sluice, and an embankment carried from the dam to join it. Immediately below the locks, is a basin large enough for steam-boats to pass each other, and the extension below to the river, averaged eight or nine feet cutting, for a length of 450 yards, through a hard gritty sandstone.

*Plate 3, fig.* 10.—The work at *Smith's Falls*, three-quarters of a mile above, consist of three combined and one detached lock, with a stone dam and waste-weir at the head of the first, and a small wooden waste-weir to raise the water to the level of the canal above the latter. The locks are all on the right bank of the river, and the excavation was through an irregular mass of rock full of fissures and springs. Upon this foundation the three locks are built; their combined lifts being twenty-five feet, with seven-feet water below, and five feet six inches on the sill of the upper; across the chamber-walls of the centre lock is a rolling bridge, and immediately above the locks a large basin is formed by embankments, extending on the south side 850 feet from the wing-wall, to meet the canal below the detached lock; and on the other, 180 feet to a cut-stone pier, which forms the abutment to a waste-weir constructed of timber, with four sluices to regulate the height of water, and extending 200 feet, to a rocky island, from the opposite side of which the stone dam crosses the river. This was built on the same plan as that at the work below, and was in some danger during its construction; its height is twenty-three feet, having been raised six feet above the required surface of the canal, to prevent the water flowing over it, as was at first intended. The depth of water in the basin, and in the canal, to the single lock, about 600 yards above, is five feet six inches, and the lift of this lock, which is built upon a solid rock foundation, is eight feet, allowing seven-feet water on the upper sill, which is retained to that level by a low wooden dam or waste-weir about four feet high, crossing the river nearly abreast of the upper-wing walls of the lock, from which on the south side an embankment extends, till it meets the high land, formed by two rough stone walls with puddle between them, and a slope of earth on each side, guarded of course against the rise of the river. The canal excavation extends about 300 yards above, and the same distance below this single lock.

A village has risen at this place since the first commencement of the canal, on the opposite side of the river; and as there are very good tracts of land, and several settlements in its rear, it will probably become of some comparative importance. Mills upon a large scale have been built by the first contractor for the work, behind the waste-weir of the stone dam; and they are connected with the houses on the opposite side by a wooden bridge crossing the rocky ravine, which was formerly the bed of the river, and down which still flows a quantity of water, that turns the abutments of the dam, through large fissures in the loose rock.

*Plate* 3, *fig*. 11.—A little more than two miles above *Smith's Falls*, is a canal with a single lock, also on the right bank, at what was called the "*First Rapids on the Rideau*," the lift of which, six feet four inches, brings the navigation to the average summer-level of the Rideau Lake. The canal is a mile and a quarter in length, and the lock is situated about the centre; the excavation, above and below, being principally limestone rock. In the lock-pit it was through a ridge of stiff clay with boulders, from eighteen to twenty-three feet deep, and the floor is of hemlock plank laid upon sleepers of the same wood. The sills, and part of the breastwork, were laid in cement, as were most of the works above Long Island, and the walls have a guard of four feet eight inches over the surface of the seven-feet water in the canal. A lay-by for boats is excavated on the south side of the canal above, about half way between the lock and the river, and an embankment runs for a great part of the distance on the opposite side. At the head, the cutting is deeper, averaging about ten feet. Nearly abreast of the upper entrance of the canal, the dam crosses the river, formed like that at Maitland's Rapids, of a sill, upright, and brace of oak, the former bolted to the rock: with pine or hemlock logs across the intervals between the bays, the whole backed with steps of heavy rough stone, four bays can be removed entirely, and the upper row of the whole dam, 365 feet long, to prevent any great rise of the lake in the spring. Cockburn Creek, which enters the Rideau just abreast of the lock, rises, as has been already mentioned, near the Mississippi.

About four miles above this work, the river Tay empties itself into the lake on its north shore. A canal has been formed from Perth, eleven miles up this stream, by the inhabitants, to join the Rideau, calculated for steam-boats of twenty-feet beam, and drawing nearly four-feet water. The difference of level from the water below the town of Perth to the Rideau Lake, was twenty-eight feet, and the different rapids that composed this fall were converted into pools of still-water by dams, on the same principle as the Rideau. The whole work consisted of six dams with waste-wiers, and five locks; of which four were of rubble masonry, and the fifth of wood. It was commenced in 1831, and finished in 1833, excepting the lower pair of gates of the lowest lock, which they could not manage to hang for some time. In a commercial point of view, this canal, though rough in its construction, and composed of not very durable materials, will, in connexion with the Rideau, be of incalculable benefit to

Perth and the country in its vicinity, as they had formerly no nearer market than Brockville, the road to which crossed a contracted part of the lake at "Oliver's Ferry," seven miles above the first Rapids. The length of the lake, from the last named works to the *Upper Narrows*, is twenty miles.

*Plate* 3, *fig*. 12.—The original channel is here closed by a wooden waste-weir, and a lock of four feet ten inches lift, built in a cut made through a narrow tongue of land. The foundation is a solid rock, which has been sunk three feet lower than was necessary. There is no breastwork, the lift being thrown on the upper gates, and both the sills are of oak bolted to the rock. On the north shore the land is bold and rocky, but on the opposite side an embankment has been carried from the waste-weir for some distance.

The object of raising this part of the lake, instead of keeping the natural level of the whole as the summit, was to save the expense and trouble of some very difficult rock excavation at the isthmus, between the Rideau and Mud Lakes, the entrance to which is just three miles distant.

The length of this piece of canal is about a mile and a half, and a great portion of it is through a very difficult rock, partly granite: with the idea of saving a little excavation, the winding course of a gully, rather lower than the straight cut, was adopted, and the turns were afterwards found so abrupt, that many of the corners had to be cut away near the Mud Lake. The cutting is very heavy, above twenty feet, and the lock is built close to the shore, on a rock foundation, without any breastwork; the lift of eight feet being thrown on the upper gates; a block-house is built close to the lock. Had the Mud Lake been raised to the same level as the Upper Rideau, by placing this lock as an addition to that at Chaffey's Mills, and the lift of four feet ten inches at the Narrows, added to that of six feet four inches at the First Rapids, the summit-level would have extended the whole distance between this place and Chaffey's Mills, about thirty miles, and the work at the Narrows have been reduced to merely deepening the old channel, or making a short cut across the tongue of land. Some low ground must of course have been flooded by this plan, both on the shores of the Lower Rideau and Mud Lakes, but it is of little value, when compared with the saving it would have occasioned.

Descending into Mud Lake, the route continues, through the narrow channel before alluded to, into Clear Lake, and from thence enters Indian Lake, through a cut of about 180 feet connecting them.

*Plate* 3, *fig*. 13.—At the outlet of this last, in a creek where originally were situated *Chaffey's Mills*, is a single lock of ten feet two inches lift, about five miles distant from that at the isthmus, seven-feet water is (at the average level of the lake) on the upper sill, and the same depth in the lock. The floor is rock, and the material used for building, entirely sandstone, obtained partly close to the works, and partly at a large quarry a few miles distant, which supplied most of the contractors for this part of the canal. A channel is cut round the lock, to carry off the surplus water in the spring, with a waste-weir. The lock-walls have a guard of six feet six inches over the surface of the lake.

*Plate* 3, *fig*. 14.—The creek below this work, winding between banks hardly above the level of the water, leads into Musquito, or Opinicon Lake, and within a few hundred yards is the outlet into Sand Lake, where, on the site formerly occupied by *Davis's Mills*, is a single lock, built of the same stone as that used at the last work, with a lift of nine feet nine inches between the surfaces of the two lakes; seven-feet water being in the lock, and seven feet nine inches on the upper sill. A waste channel is cut round a rocky knoll on the left bank of the creek, where Davis's house originally stood, and the surplus water flows over a waste-weir into the lake below. The embankment, from the head of the lock, to join the high land, consists of two rough stone walls three feet apart, with clay-puddle rammed between them, and backed on each side with earth and stone from the excavation. The lock-walls have a guard of five feet above the level of the lake. This work is two miles and a half distant from Chaffey's, and three miles across Sand Lake, to the next in succession at "*Jones's Falls*."

*Plate* 3, *fig*. 15.—The works at this station are perhaps the most striking of any on the whole line of communication, both from their wild situation, and their magnitude. The dam built across the ravine, down which the waters from all the small lakes above found an outlet, is sixty-one feet high, and about 130 yards long on the top, abutting on each side on the high rocky banks, consisting of sandstone and a species of granite. The dam itself is built of the former stone, large smooth blocks of which are laid on edge, breaking joint all the way up: the thickness of this wall is about twelve feet at top, and the backing of stone and clay extends about sixty feet, with a slope of about five to one up stream. The whole base must between three and four hundred feet.

By forming temporary sluices of rough masonry laid in mortar, alternately on each side of the dam at different heights, to carry off the water as it was raised by the progress of the works, the contractor, Mr. Redpath, who was luckily well qualified for the task, managed to raise this enormous mass to its height without any serious impediment. The water is turned by it down a ravine, about a quarter of a mile long on the right bank, opening a little above the dam. A narrow channel has been cut through the granite rock bounding this hollow, to a depth of fifteen feet below the raised surface of the lake, and a strong framed waste-weir, with sluices in the bottom, placed in it, its top on a level with the water. By this channel and the sluices its depth is regulated, and the surplus finds its way into the old watercourse, a little below the dam. A single lock of fifteen feet two inches lift is placed about the middle of this ravine, its walls having a guard of five feet over the surface water. A basin bounded by the high rocks, connects this with the three combined locks, of which the two upper have each a lift of fifteen feet, and the river-lock thirteen feet; this supposes seven feet water to be retained in it: and also seven feet on the upper sill or the detached lock, but only five feet in that of the upper of the three combined.

These locks are all built on invert arches, and of the same species of sandstone used at the two last works. They have altogether a most beautiful appearance, and seem hitherto to have answered perfectly, notwithstanding their dangerously high lifts. More care was taken with the breastworks and sills, than with those of the other locks, and they have been secured with bolts and strong iron straps since their first trial. The gates also are necessarily of a stronger construction.

The navigation continues below these locks, through Cranberry Lake, along a muddy creek, winding among a quantity of drowned swampy land, and across Cranberry Marsh, entering the Cataroqui through a passage cut round the site of the old dam at the *Round Tail:* three quarters of a mile below which are the works at *Brewer's Upper Mills*, distant from Jones's Falls about eleven miles.

*Plate* 3, *fig*. 16.—The waters are kept up to their required level by a dam at this place, instead of that formerly situated at the Round Tail. It is of framed timber, similar to those described at some of the works on the Rideau, eighteen feet high, and backed with a quantity of large blocks of stones piled behind its whole height, with a slope of gravel or clay in front. The water does not flow over it as was intended, but is carried off by a sluice-way on the left of the dam. The two combined locks are on the right bank of the Cataroqui, at the end of a cut of nearly 400 yards, with a large basin immediately above them in which the water is retained by a substantial earth embankment on the river side.

They are built on a clay foundation, and floored with timber; the lift of the upper lock six feet, and that of the lower eleven feet six inches, the upper sill having one foot more water on it than in the lower lock at Jones's Falls. On the lower sill it is seven feet deep. The guard of the walls of the upper lock is four feet, which is necessary to provide against the rise in the spring, the Cataroqui being the outlet of a chain of small lakes lying to the westward.

*Plate* 3, *fig*. 17.—At *Brewer's Lower Mills*, one mile and three-quarters distant, another wooden dam, about thirteen feet high, is constructed across the river, to retain sufficient water between these two works; and a single lock is built on the left bank, on a clay foundation, entered from a cut of about half a mile long, made through the low swampy land, to avoid an abrupt bend in the creek; the floor is of wood, and the lift of the lock thirteen feet two inches, allowing seven-feet water on both upper and lower sills, with a guard of three feet two inches on the walls.

From hence to *Kingston Mills*, ten miles and a half distant, the water is kept up to a level by the dam constructed at the latter place. The old course of the stream is followed for the greater part of the distance, with occasional cuts across its bends to shorten the distance; but near Kingston Mills, the flat marshy country through which it flowed is completely inundated, and all traces of the old Cataroqui have vanished. The channel is here marked out through the mass of dead timber on each side, presenting the most desolate appearance.

*Plate* 3, *fig*. 18.—The dam at *Kingston Mills*, which retains the waters to this level, is constructed on the same principle as the others, of stone placed on edge. Its height is about thirty feet, and the length on the top, from the rock on which it abuts, near the wing-wall of the upper lock on the right bank, to the cut-stone pier of the sluice-way, which joins its abutment on the left, near 400 feet. There is a far larger mass of clay and broken stone at the back of the key-work than was originally intended, with a very gradual slope up stream. An earthen embankment extends to the west, from the sluice-way, for about 1000 yards, till it meets the high land, and a similar mound of nearly the same length is also raised across some low land to the eastward, to prevent the water from turning the works. The locks, built of limestone, are four in number, the upper being detached, with a large basin between it and the other three, which are combined, and of an extra thickness on the river side, being without any backing, and faced with ashlar. The lift of the detached lock is eleven feet eight inches, allowing seven feet eight inches water on the upper sill, and five feet in the basin, which is retained on the west by a large earthen embankment faced with a stone wall. A species of lay-by, or dock, is connected on the east side with this basin, large enough to receive a steam-boat, and with piers to which gates may be hung. The lifts of the other three are also eleven feet eight inches each, allowing eight-feet water in the river lock, making a total lift of forty-six feet eight inches from the surface of Lake Ontario to that of the Cataroqoi, as raised by the present dam; and a long wooden bridge crosses the upper lock, the road to Montreal passing over it. The excavation was through a species of granite, and was an expensive as well as tedious undertaking, rendered still more so by the difficulty of procuring hands in the spring and autumn, owing to the very unhealthy situation. At all the works between the isthmus and Kingston, as well as some on the other side of the Rideau Lake, the same delay was experienced from this cause. At the head of the bay where the Rideau canal enters Lake Ontario, the depth of water is at all seasons sufficient, but within a mile of the locks a rocky shoal, as has been mentioned, crosses the route. A coffer-dam was at an early stage of the work formed round a narrow part of the channel purposed to be deepened; but the canal was completed, and in operation, before any thing was done to remove this impediment; so that the steam-boats were obliged, at certain seasons, to unload at Kingston Mills, there not being four-feet water over this bar. A channel has however since been cut round it, without meeting with any rock that required blasting under water, and the communication is now uninterrupted to Kingston, five miles distant from the mills.

The size of the locks being the same throughout the whole line, their description has been deferred till now, as well as the general dimensions of the breadth and slopes of the dams and the excavations. The enlarged locks, as authorized by the committee in 1828, are calculated to pass a boat 108 feet long, clear of opening the gates, and thirty feet wide over the paddle-boxes. Their length between the pointed sills is 134 feet, and breadth between the upright piers thirty-three feet. The chamber-walls are ninety-five feet long, eight feet thick at bottom, and five feet at top (the batter varying of course with the height, which in combined locks has an awkward appearance). Deviations have been made in some of the works in the breadth of the walls and piers; but any detailed account of these alterations and their causes, would be foreign to this report.

Such of the locks as are upon a rock foundation, required of course no floor. Those upon clay were generally built upon an inverted arch, but the floors of several last constructed are of hemlock or oak planking, laid upon sleepers of pine or hemlock, and are found to answer perfectly well. Piles were in hardly any instances used, and then only partially in front of the breastwork. The walls, including the ashlar facing, were laid in common mortar, and the joints pointed with cement, and cement grout subsequently forced into them in the manner already described.

The lower sills of the single locks, and of the sets of combined locks, are of oak, framed and planked, and where the foundation is rock the floors of the recesses are planked also. In those which have no breastwork both sills are of wood.

In most of the locks the stone sills only are of ashlar, cut to a mould; but at some of the works last completed, several courses of the breastwork below were cut, joggled, and laid in cement; precautions that ought to have been taken with all, and which would have saved the necessity of the long fox wedge-bolts and iron straps, subsequently found requisite to retain the sill-stones in their places. The upper sluices are placed in the centre of the culverts formed in the piers, and have of course a greater pressure to bear than if they had been at the upper opening on the pavement above. They turn on a horizontal axis, and are worked by a double chain passing round a crab placed over the man-hole. Originally they were of oak, but being found unequal to the pressure, cast-iron gates were substituted, which had afterwards to be strengthened with bars of wrought iron. The gates are of oak, planked with the same wood, or pine, and the scantling of the framework was the same for the high and low lifts. For the lower gates, and in the high lifts, they were found too weak, and have been since strengthened by additional braces. They were at first worked by a double chain passing round a crab on the pier above; one end of the chain was fixed to the front of the gate near to the mitre-post, it was then led along blocks, bolted for that purpose to the pavement, up the wall to the crab: after a couple of turns round the barrel of the crab, it was again passed down the wall along the same blocks on the pavement, round a pulley fixed to the sill, and then fastened to the back of the gate. This plan was so far convenient, that one crab answered the purpose of both opening and shutting the gates; but it has since been found so liable to get out of order, and, in the case of the lower gates, so likely to cause delay and expense from a pebble or chip of wood getting entangled in the blocks, or chain, below water, that the whole system has been changed since the first year the canal came into operation. The lifts are in many cases higher than is general, or perhaps prudent; and in the connected locks, they are in some instances so unequal, that some trouble is experienced in managing the supply of water from one to another, as a lock of five-feet lift naturally will not supply sufficient water for one of ten. The invert arches can also hardly be said to act in the way their name implies; as the joints of the course of ashlar forming the floor, are only dressed a few inches, and of course the stones are not in sufficiently close contact. Luckily there is not a single instance of really a bad foundation throughout the line: the worst were perhaps at Hartwell's and the Hog's Back.

The dams were originally designed in all cases to act as waste-weirs, but the first experiment at the Black Rapids showed the impracticability of this plan, even in the case of one of the lowest dams built on the solid rocky bed of the river. They were, however, mostly commenced with this design, and the sluice-ways have generally been constructed in the opening left by the contractor to carry off the water during the erection of the dam; had they formed part of the original plan, they would in most cases have been differently placed, and the method adopted to regulate the height of water, better than the present clumsy one of raising and lowering squared logs thirty feet long, down grooves in the piers, which under a pressure of water is a most troublesome operation. The shape of all the stone dams is a segment of a circle, whose radius is about equal to the chord of the arc, and the masonry is formed of stones of different lengths placed on edge, so as to break joint. This construction was adopted with a view to their acting as an arch, which can seldom be the case, owing to the want of solid abutments. The base of the stonework, called in the contracts "arched key-work," varied according to the height of the dam. At the Hog's Back it was intended to be twenty-one feet; in dams from eight to twelve feet high, eight feet; and all to have a slope of one-eighth their height. Clay-puddle is rammed behind this wall for a breadth of from five to eight feet, backed by a mass of earth up stream, with a base of about three to one (in some of the contracts an angle of twenty-three degrees), which however has been greatly increased in all the dams formed on this plan. Two of the last built (at Nicholson's and Edmons' Rapids) are rather different in their construction, and of a smaller section; broken stone and gravel being substituted for clay, which has been found to answer much better; and at the lowest lifts wood has been used instead of stone. The higher dams are decidedly too great an extension of a good principle: their work in building, the serious consequences which must result from any injury when built, and the number of connected locks they require to surmount their level, often more than balance the advantages of saving excavation, and the additional masonry and lock-gates. The excavation for such parts of the communication as really come under the denomination of a canal, is generally about twenty-eight feet wide at bottom, with a slope of two feet to one. In rock, however, the sides are nearly vertical; and where the cutting was trifling, and the line not straight, the breadth is in some places increased. Any detailed description of the machinery used in working, or building the locks, or of the more minute dimensions of the different parts of the work, would be out of place in this general account, which will close with a statement of the average prices of the different principal items in the contracts, and of labour and materials in Halifax currency. Plans and drawings of the locks and machinery were to have accompanied this report, but they have been reserved till a description can be given of the alterations which have been made in them since their original construction.

| | | Halifax Currency. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | £ | s. | d. | | £ | s. | d. |
| | Chopping and cleaning, per acre | 4 | 0 | 0 | to | 4 | 10 | 0 |
| | Grubbing stumps, do. | 15 | 0 | 0 | — | 16 | 0 | 0 |
| Per cubic yard. | Earth excavation under six feet | 0 | 0 | 0 | — | 0 | 0 | 6 |
| Per cubic yard. | Ditto „ above six feet deep | 0 | 0 | 9 | — | 0 | 1 | 0 |
| Per cubic yard. | Hardpans (clay and gravel) | 0 | 0 | 0 | — | 0 | 1 | 6 |
| Per cubic yard. | Rock excavation, shelly limestone | 0 | 3 | 6 | — | 0 | 4 | 0 |
| Per cubic yard. | Ditto „ granite, &c. | 0 | 4 | 6 | — | 0 | 6 | 0 |
| Per cubic yard. | Puddling | 0 | 0 | 0 | — | 0 | 1 | 6 |
| Per cubic yard. | Embankments | 0 | 0 | 9 | — | 0 | 1 | 0 |
| Per cubic yard. | Dams, including "arched key-work," puddling, and whole section of earth | 0 | 4 | 0 | — | 0 | 6 | 0 |
| | Masonry of the locks, per cube foot | 0 | 1 | 0 | — | 0 | 1 | 6 |
| | Oak timber squared, per cube foot, the price increasing with the scantling | 0 | 0 | 4 | — | 0 | 1 | 0 |
| | Pine and hemlock, ditto | 0 | 0 | 3 | — | 0 | 0 | 6 |

The gates were made partly by carpenters employed in the workshops on day-work, and partly by contract at 100*l.* per pair, taking upper and lower gates together, the iron work and timber being supplied by Government, but the workmanship, fitting, and hanging, done by the contractor. None of this iron work was done by contract, but the blocks, crabs, and all castings were procured principally from founderies in the Lower Province.

The prices of labour were nearly as follows:—

| | s. | d. | | s. | d. | |
|---|---|---|---|---|---|---|
| Carpenters ............ | 5 | 0 | to | 5 | 6 | |
| Masons................ | 5 | 0 | — | 6 | 6 | |
| Stone-cutters .......... | 6 | 0 | — | 7 | 0 | principally by measurement. |
| Labourers.............. | 2 | 6 | — | 3 | 6 | |
| Sawyers .............. | 5 | 3 | — | 6 | 0 | |
| Smiths ................ | 5 | 0 | — | 6 | 0 | |

Of the total expense of the Rideau it is impossible to speak precisely, as many of the individuals whose property was flooded, or required for the purposes of the canal, received compensation during the progress of the work; though the greater part of these claims are still under consideration, an officer having been appointed on the part of Government to investigate and report upon them.

| | £ | s. | d. |
|---|---|---|---|
| The amount expended up to the 31st December, 1830, appears, by the documents published for the information of the House of Commons, to be.................. ............. | 715,408 | 15 | 6 |
| And the estimate for the following year, to complete the works, was.................................. | 88,365 | 10 | 0 |
| Making a total of ......................... | £803,774 | 5 | 6 |

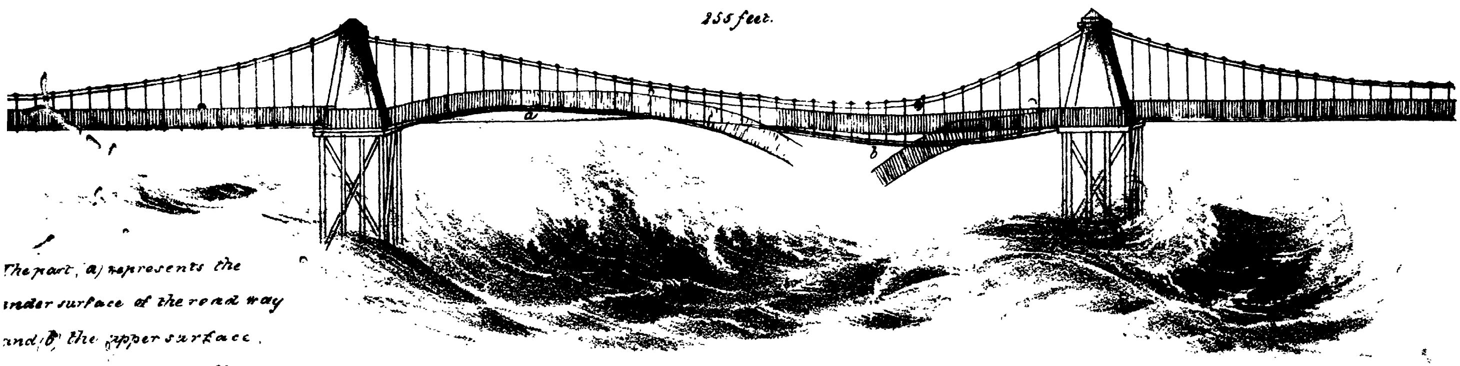
This estimate includes 20,000*l.* for the purchase of land required for Government purposes, and 14,000*l.* for compensation to individuals. It is probable that this sum has fallen short of the whole expense of the communication, including the block-house for the defence of the most exposed stations; and, that taking the amount awarded for damages into consideration, and the alteration in the system of working the gates, &c. the whole cost of the canal will not be under 900,000*l.*

E. C. FROME,

**Lieutenant, Royal Engineers.**

**Chatham,**

**28th Feb. 1837.**




The part (a) represents the under surface of the road way and (b) the upper surface, which were both visible at the same time.

SKETCH Shewing the appearance of the 3rd Span after it gave way.

Lithog at the Royal Engineer Est. Chatham

From a Sketch by Lieut. Colonel Reid

## XV.—*A Short Account of the Failure of a Part of the Brighton Chain-Pier, in the Gale of the 30th of November*, 1836. *By Lieutenant-Colonel* Reid, *Royal Engineers.*

The same span of the Brighton Chain-pier (the third from the shore) has now twice given way in a storm. The first time it happened in a dark night, and the storm was accompanied by much thunder and lightning: the general opinion of those who do not inquire into the causes of such matters was, that it was destroyed by lightning; but the persons employed about the pier, and whose business it was to repair it, were satisfied that the first fracture was neither caused by lightning nor by the waters, but by the wind.

The fracture this year was similar to the former, and the cause evidently the same. This time, it gave way half an hour after mid-day, on the 30th of November, 1836, and a great number of persons were therefore enabled to see it.

The upper one of the two sketches annexed, shows the greatest degree of undulation it arrived at before the road-way broke; and the under one shows its state after it broke: but the great chains from which the road is suspended remained entire.

When this span became relieved from a portion of its load by the road-way falling into the sea, its two piers went a little on one side, and the curve of the chain became less, as in the sketch. The second and fourth spans in these sketches are drawn straight, merely to show better the degree of undulation of the third span. These also undulated greatly during the storm, but not in the same degree as the third span. A movement of the same kind in the road-way has always been sensibly felt by persons walking on it in high winds; but on the 29th of November, 1836, the wind had almost the same violence as in a tropical hurricane, since it unroofed houses and threw down trees. To those who were at Brighton at the time, the effect of such a storm on the chain-pier was matter of interest and great curiosity. For a considerable time, the undulations of all the spans seemed nearly equal. The gale became a storm about eleven o'clock in the forenoon, and by noon it blew very hard. Up to this period many persons from curiosity went across the first span, and a few were seen at the further end; but soon after mid-day the latteral oscillations of the third span increased to a degree to make it doubtful whether the work could withstand the storm; and soon afterwards, the oscillating motion across the road-way seemed to the eye to be lost in the undulating one, which in the third span was much greater than in the other three: the undulatory motion which was along the length of the road is that which is shown in the first sketch; but there was also an oscillating motion of the great chains across the work, though the one seemed to destroy the other, as they did not both (at least as far as could be seen) take place in a marked manner at the same time.

At last the railing on the east side was seen to be breaking away, falling into the sea; and immediately the undulations increased: and when the railing on this side was nearly all gone, the undulations were quite as great as represented in the drawing.

The ends of the joists of the road-way rest upon iron girders about one inch thick and five inches deep. They are made in lengths which are fixed together by oval-bolts. The road-way seemed, therefore, to shake like a chain, and become, in fact, one with long links; and, on examining the work after the storm, the girders appeared to have broken at the holes made for these oval connecting bolts.

After the rail on one side gave way (whilst the other remained), the undulations of the two sides of the road-way became unequal; so that, whilst half the *top* of the road was seen at one end of the span, half the *under part* of the road was visible at the other end, and this latter has been shaded in the sketch, to endeavour to show it. Its motion was like that of a boat in a cross sea. It broke in five or ten minutes after the side-railway was destroyed.

As the suspension-rods are only hung up to the great chains by cast-iron caps, resting on these chains, without being fastened, some were thrown off: but most of the suspension-rods (which are about one inch and a half round rod iron) broke, and parts of them were seen hanging, as in the second sketch, from the great chains. Had the road-way been stiffened, either by a good trussed railing, or otherwise, it probably would have withstood this storm. From its oscillating side-ways as well as undulating along its length, it seems to require stiffening against both these motions. The rail which broke away was only of upright bars; and there is no cross bracing to any part, excepting to the timber piles of the pier.

The Brighton chain-pier consists of four spans of 255 feet each. It rests on piles, through which the waves roll, meeting with little resistance. The piles have stood well ever since they were loaded and the work finished; but previous to that, whilst the work was in progress, much difficulty was encountered from the piles being frequently drawn by the water floating them, and storms deranging them. The contractor who was engaged to execute the work, discouraged by the difficulties, gave it up; after which Captain Brown, of the Royal Navy, the projector of it, undertook to finish it, and succeeded, the persons he employed being principally seamen. It is expected that the damage which has now occurred, will be repaired at the expense of 1000*l*.

W. REID,

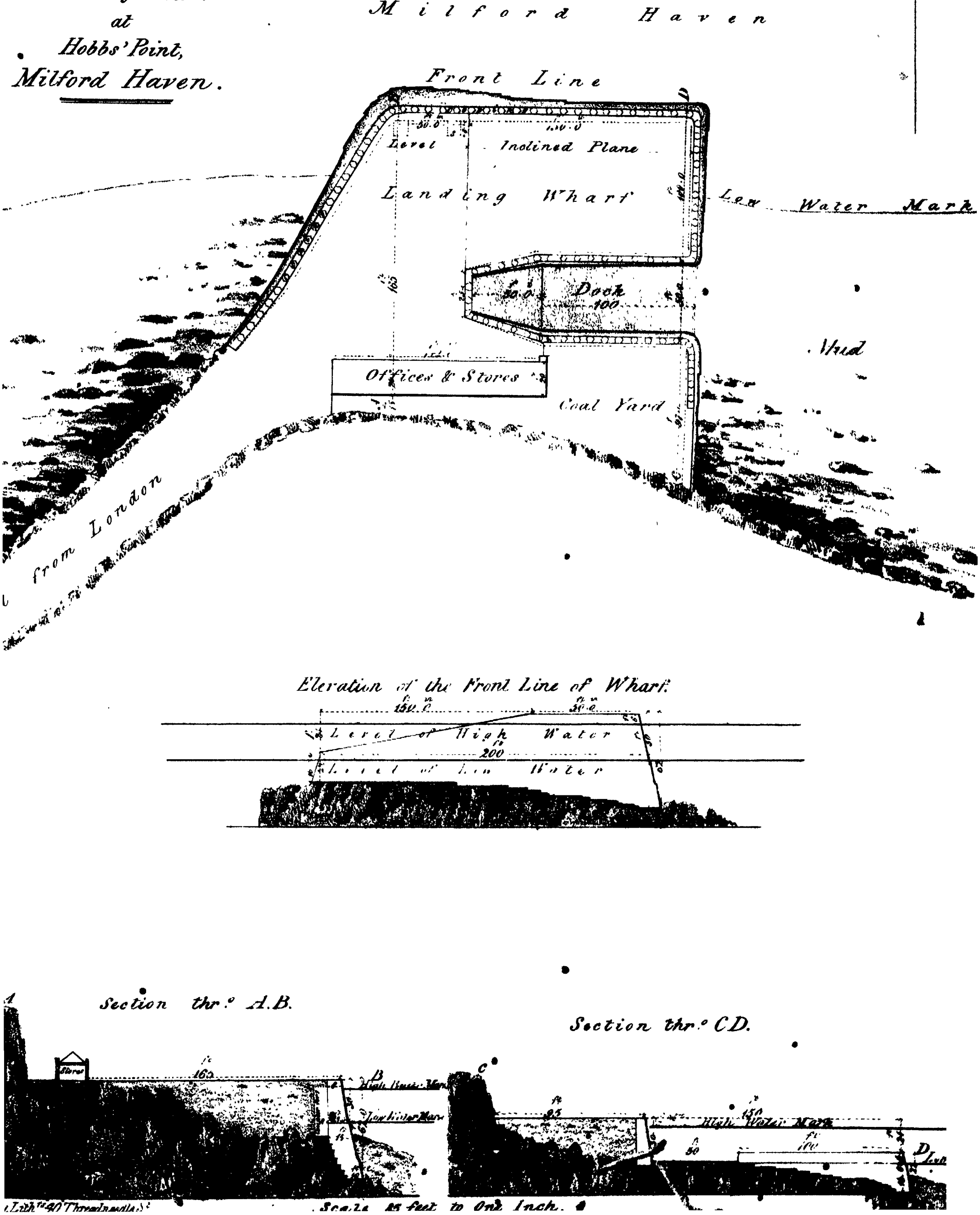
Lieutenant-Colonel, Royal Engineers.

## XVI.—*Description of the Landing Wharf erected at Hobbs' Point, Milford Haven, for the Accommodation of His Majesty's Post Office Steam-Packet Establishment at that Station, built under the Superintendence of Captain* SAVAGE, *Royal Engineers.*

THE landing wharf at Hobbs' Point, is situated one mile to the eastward of His Majesty's royal dock-yard at Pembroke, and about ten miles from the entrance of Milford Haven: it is built parallel with the shore at the Point, and carried out into the sea nearly eighty feet beyond low-water spring-tides.

The front line of the landing wharf is 200 feet long, fifty feet of which at the west end is level, and the remaining 150 feet an inclined plane, so as to enable the packets to lay alongside and land their passengers, carriages, &c. at all times of tide, by means of gang-boards. The inclined plane is 100 feet wide, having a dock between it and the coal-yard: the latter is capable of containing 300 tons of coal. The dock is dry at low water (spring tides), but at high water, every day, the steamers and colliers can come into it. At the lowest spring tide, there is always twelve-feet water alongside the front line, at the foot of the inclined plane. The whole of the landing wharf is built on solid rock, to obtain which, it was found necessary on the front line to excavate from six to eighteen feet below the original bed of the haven. The height of the front wall, at the west end of the wharf, is sixty-two feet, the foundation of which is fifty-seven feet under water at the top of the highest spring tides, and thirty-two feet at the lowest. At Hobbs' Point, a low range of buildings, 142 feet long, appropriated for offices and stores, is erected parallel with, and at the distance of 165 feet from, the front line. All the work below low-water mark was constructed by means of diving-bells, a full description of which, together with the machinery, &c. used, is given in the following pages. The whole of the wharf-walls are built of limestone front ashlar, backed with large flat rubble-work laid in horizontal courses, except the north-west angle, which being the most exposed and highest part, is built with blocks of granite, in courses two feet thick, each course bolted together with one inch and a half round rod-iron. The coping is also of granite, two fees thick, dovetailed together, as shown in

# Plan Sections and Elevation of the Landing Wharf at Hobbs' Point, Milford Haven.




Lithd 40 Threadneedle St

Scale 25 feet to One Inch.

the plan. The landing wharf is supplied with bollards, ring-bolts, chains, &c. for securing the vessels whilst laying alongside. The lime used was Aberthaw, in the proportion of one of lime to two of sand.

The following are returns of the quantity and description of work performed. Return No. 1, shows what was done by means of the diving-bells under water; Return No. 2, what was built above water.

### Return No. 1.

*Bell-Work.*

| | | |
|---|---|---|
| Granite masonry, built | 5552 | cubic feet. |
| Limestone " " | 56,510 | " " |
| Solid rock, excavated and removed | 767 | cubic yards. |
| Mud, rubbish, and shingle, excavated and removed | 3043 | " " |

### Return No. 2.

*Work done above Water.*

| | | |
|---|---|---|
| Granite, masonry, coping, &c. | 12,592 | cubic feet. |
| Limestone (ashlar front) walls | 84,751 | " " |
| Rough limestone walls in buildings, walls, &c. | 10,292 | " " |
| Solid rock, excavated and removed | 439 | cubic yards. |
| Rock and rubble, " " | 14,919 | " " |
| Earth, clay, and rubbish, " | 12,660 | " " |
| Mud, rubbish, and shingle, " | 1582 | " " |

*Description of the Diving-Bells and Machinery, &c. used in the Erection of the New Pier at Hobbs' Point, Milford Haven.*

There were four bells employed, which I shall describe separately, as they all vary either in size, shape, or material.

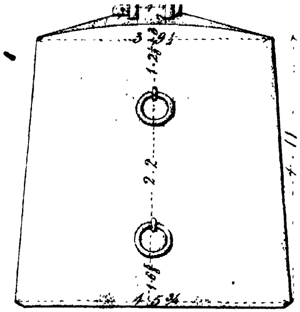
*Diving-Bell, plate 3.*—No. 1 diving-bell was made of cast iron, six feet two inches long, four feet six inches broad at the bottom (on the outside), and five feet two inches high; the sides and ends were one inch and three quarters thick at the top, and two inches and three quarters thick at the bottom; the top of the bell was one inch and three quarters thick, and strengthened by a strong longitudinal iron rib, to which the block of the fall was shackled; there were also six transverse ribs, three on each side of the longitudinal one. This bell was not quite flat at the top, but rose three inches and a half from the sides towards the centre, and was cast in one piece; it weighed four tons and a quarter. On the top were ten convex lenses, eight inches in diameter, fitted into a rabbet formed in the casting, having an iron rim screwed round them on the inside of the top of the bell to secure them: these lenses admitted sufficient light, when the water was clear, to distinguish the smallest objects (which I have been enabled to do when in the diving-bell fifty-four feet under water.)* Air was supplied to the workmen employed in it, through a leather hose, one end of which was screwed into the centre of the top of the bell, and the other into the receiver of an air-pump worked from above. The hole that admitted the air was covered on the inside of the top of the bell with a piece of circular leather, secured by eight screws, in the spaces between which the air entered and spread, avoiding thereby an unpleasant direct current. This piece of leather, should the hose burst, would also prevent any very great quantity of water from entering the bell instantly, and there was always sufficient air in it to support the workmen till they could be raised to the surface. On the outside of the bell, at each end, there were iron rings, to one of which a guy-rope was attached, for the purpose of preventing the bell from turning round, which it otherwise very frequently would, and thereby entangle the fall, so that the bell could neither be raised nor lowered. An attentive man had always charge of the guy-rope. In the inside of the bell, at each end, were moveable seats, fitted into iron ledges, cast with the bell; and at the bottom, across the centre, was a foot-board similarly secured, to placed the feet on; there was also a wooden shelf on one side near the top for small tools, &c. &c., to the front of which were a row of hooks to hang the setting bars, chains, &c. Two large eye-bolts were screwed into the top of the diving-bell, to which the heavy lime and granite stones were slung by chains and raised with it, in order to lay them in their proper places. The inside of the bell was frequently whitewashed.

No. 2 bell was very similar to No. 1, but a few inches smaller.

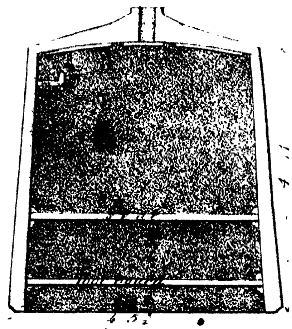
No. 3 bell was a little larger than either No. 1 or No. 2, cast in five separate pieces and rivetted together. It was five feet six inches high, seven feet two inches long, and five feet wide outside: this bell in other respects was exactly the same as No. 1 and No. 2; it weighed six tons.

* The foundation-stone of the pier is fifty-seven feet under water at the highest spring-tides.

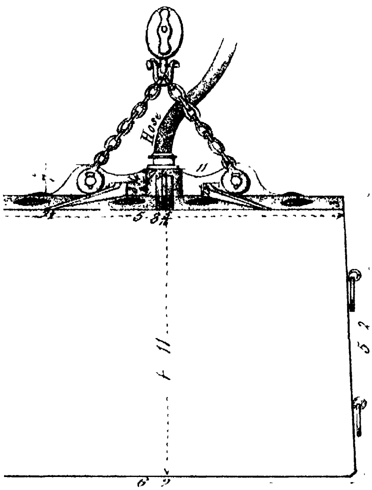
# The Diving Bell



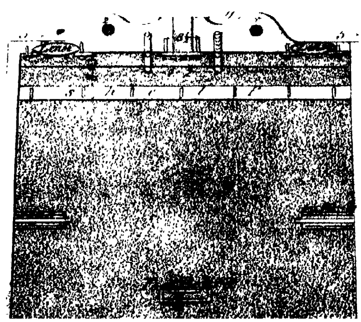

End Elevation

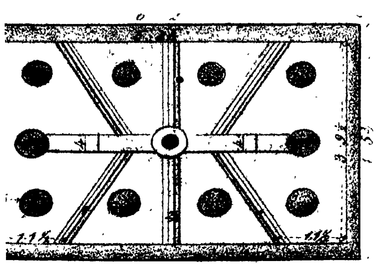



Section

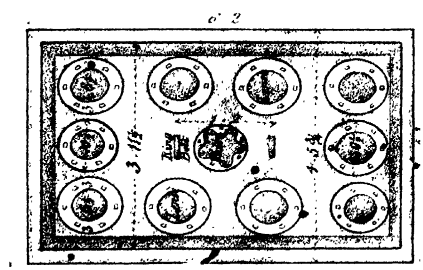



Side Elevation





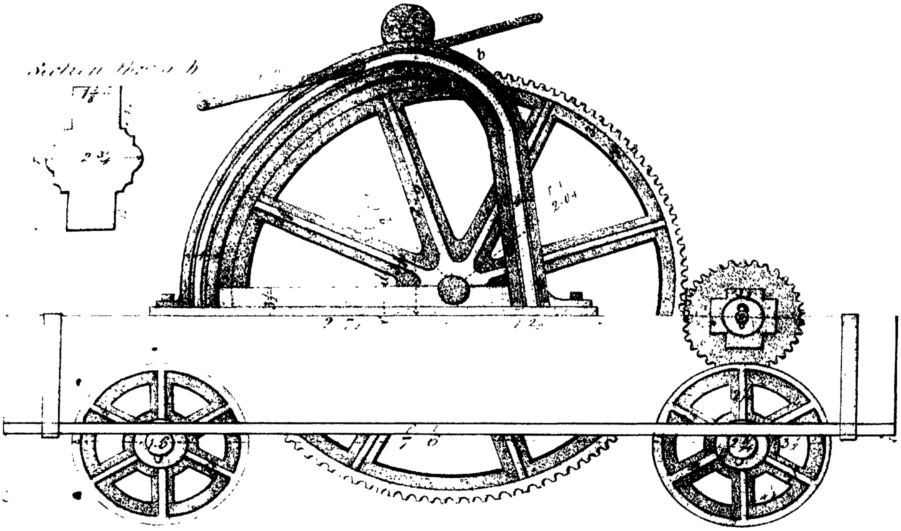
Outside Plan of the Top




Inside Plan of the Top

Fig 4.

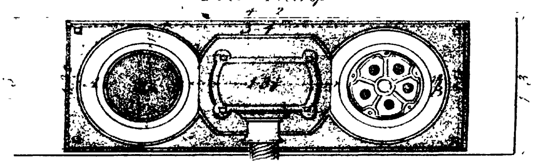
Crab




Side Elevation

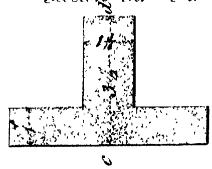
Fig 1.

Air Pump



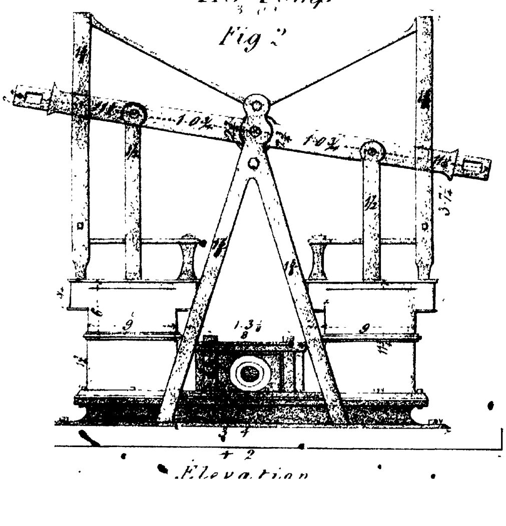
Plan

Section thr c d Fig 4.



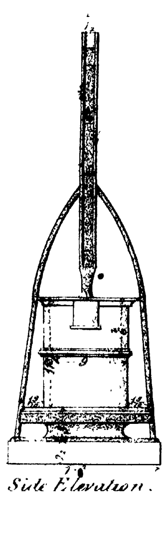
Air Pump

Fig 2



Elevation

Fig 3.



Side Elevation.

*In these sketches of the air pump the part left unshaded is brass.*

No. 4 was a small circular bell, in shape like a common church-bell; it was five feet three inches high, five feet in diameter at the bottom, and two feet nine inches at the top on the outside. Across the centre, at the bottom, was placed a board upon which the workmen sat, so that when ascending or desending, their legs were partly in the water. This bell was made of wrought-iron, in plates three feet three inches long by two feet eight inches wide, rivetted together in the same manner as the boiler of a steam-engine. The plates were three-eighths of an inch thick. This was a very inconvenient bell, from its shape, and was only used in excavating.

N. B. The annexed plans, sections, and elevations of No. 1 diving-bell will afford any further information that may be required respecting its construction. The diving-bells, when not in use, were always hove up above high water, and secured to the carriage by four hooks and chains.—*Vide* elevation of diving-bell and machinery.

## *Of the Air-Pump.*

*Diving-Bell, plate* 4, *fig.* 1, 2, 3.—The air-pumps used to supply Nos. 1, 2, and 3 bells were double ones; that attached to No. 4, was a single one; the cylinders were brass, one foot high, half an inch thick, and eight inches in diameter inside. The air was forced from the cylinders into a receiver, across the bottom of which was a double valve fixed on a piece of iron, called a saddle: this valve rose and fell as the air was either forced from the right or left hand cylinder, and was required to prevent the air from entering the opposite cylinder instead of into the hose, one end of which was screwed into the front of the receiver, and the other into the top of the diving-bell. The double air-pump required from four to six men to work it, according to the depth of water the bell was working in, the nature of the work, or the number of persons in it.

## *Of the Hose.*

The hoses were made of cow-hide double, nearly a quarter of an inch thick, between which there was a layer of coarse duck, well rubbed over with currier's dubbing; the leather was tongued at the seam, the edges thinned, turned down, and stitched through the whole. The hoses were made in lengths of about eighteen feet long, which were joined together by a brass male and female screw;

they required to be well greased every two or three weeks with a mixture of tallow and bees-wax; in cold weather, the quantity of the latter article was very small, but in summer more was required, to give solidity to the composition. The diameter of the hose was about two inches and a half; if well made and taken care of, one would last five or six years.

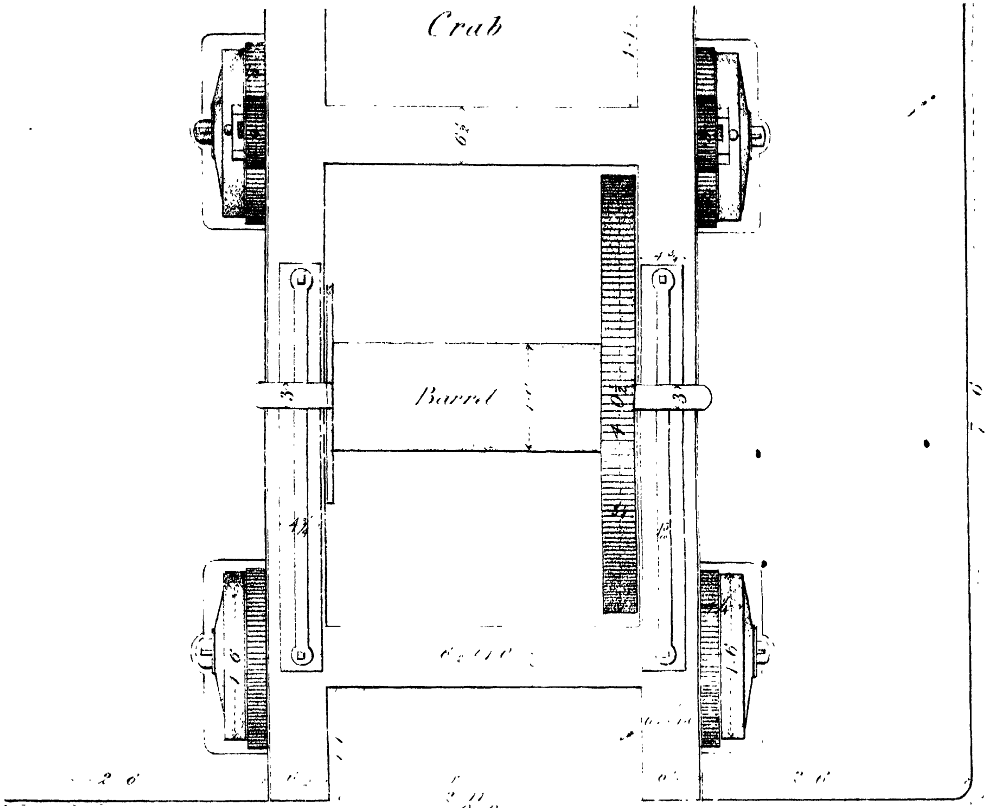
The hoses when in use ought to be supported at the joints by small lines, in order to prevent their being strained.—*Vide* elevation of diving-bell and machinery.—*Plate* 2.

### *Of the Crab, &c.*

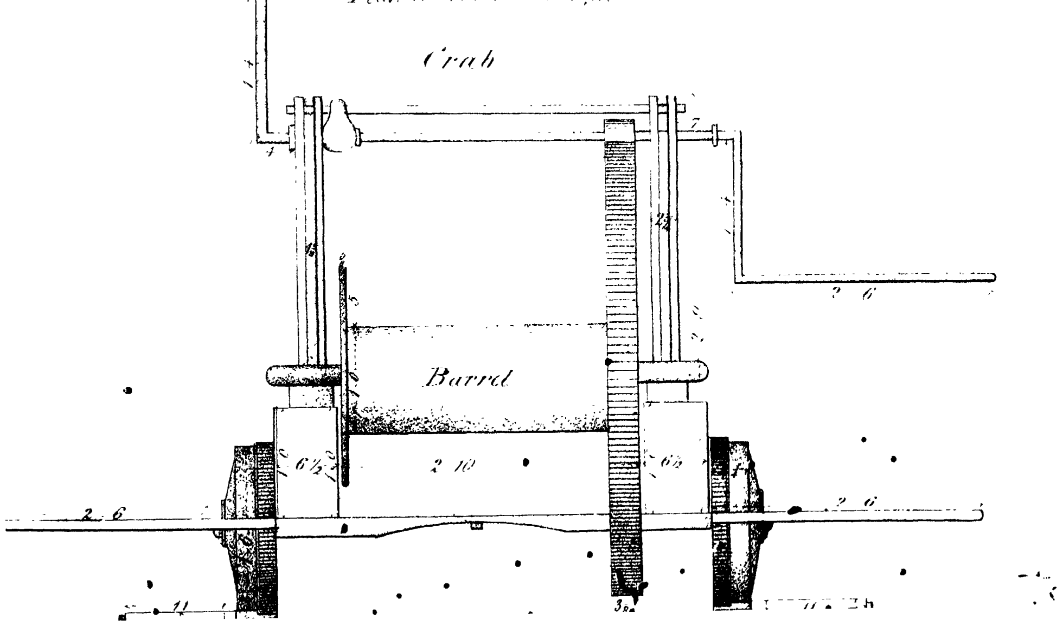
*Diving-Bell, plate* 4 *and* 5.—Each bell was suspended from a cast-iron crab, mounted upon a small wooden carriage, having four cast-iron wheels attached to it; over the two front ones, small pinion-wheels were placed, which were turned by a short iron bar being inserted into holes made into them for this purpose: by this means the bell was moved with the greatest facility from the front to the back of the wall. The wheels of the crab-carriage moved on a rail-road fixed on the top of a large carriage upon which they were placed. One end of the bell-fall was fastened to the frame of the crab-carriages, and the other to the barrel of the crab, passing through a double block at the top, and a treble one at the bottom. The lower block was secured to the diving-bell by strong chains, which were run through three strong iron shackles, one of which was bolted to the lower block, and the other two to each end of the longitudinal rib on the top of the bell. The fall was a seven-inch shroud-layed rope in six parts. Two men were sufficient to raise or lower the bell when it was under water, but it required six or eight to raise it when out, or coming out. A crab and carriage similar to the one to which the bell was attached, was used for lowering down the large blocks of granite and limestone,

### *Of the large Stage Carriage.*

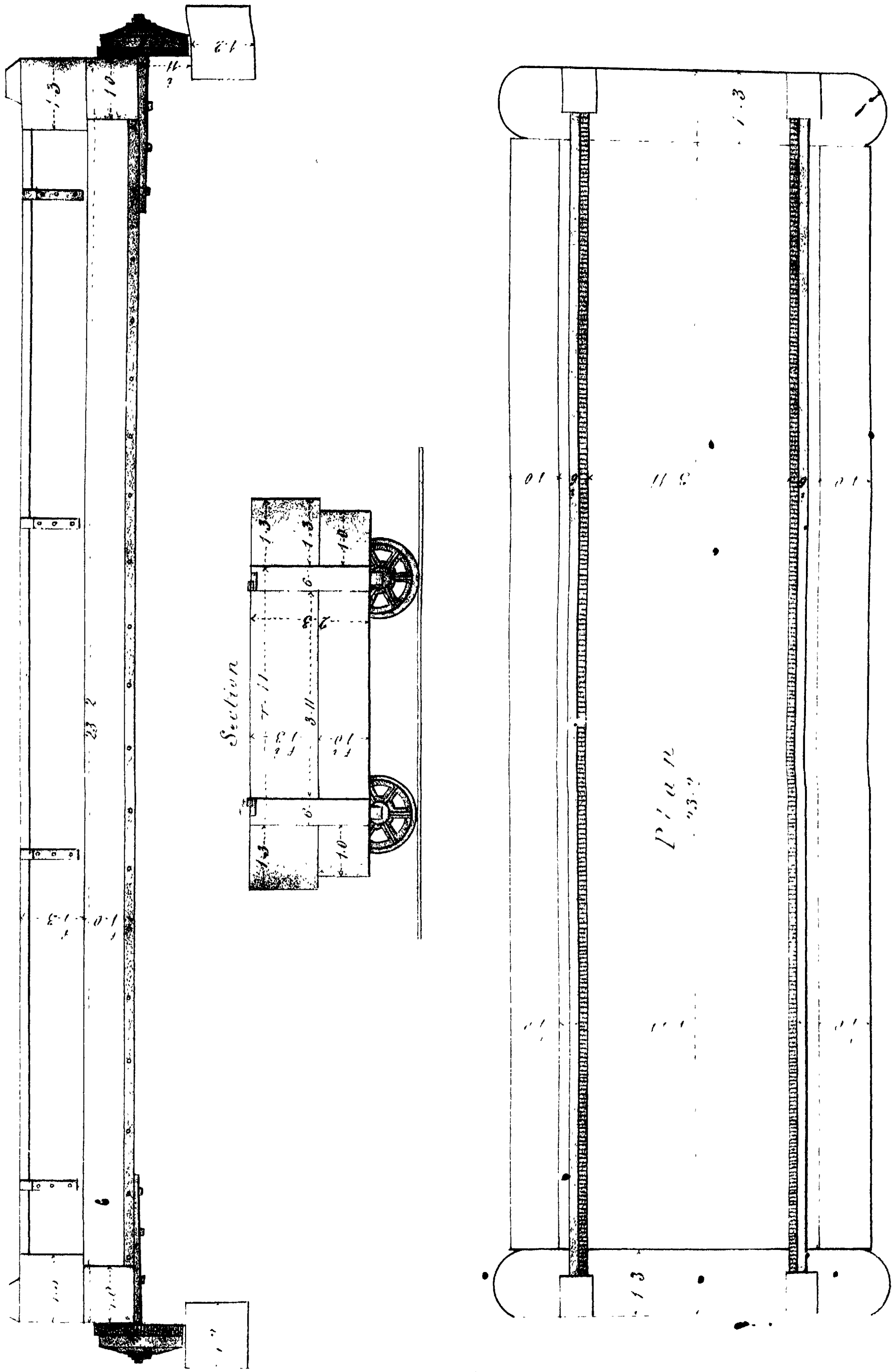
*Diving-Bell, plate* 6.—This carriage was twenty-four feet long, and six feet eleven inches wide on the outside of the frame, mounted on four cast-iron wheels, having two small pinion-wheels placed over two of them, one at each end, which were turned by a short iron bar. This carriage moved on a rail-road laid on the stage; by this means the diving-bell was easily removed from one end to the other of the wall.




Plan of Crab & Carriage.

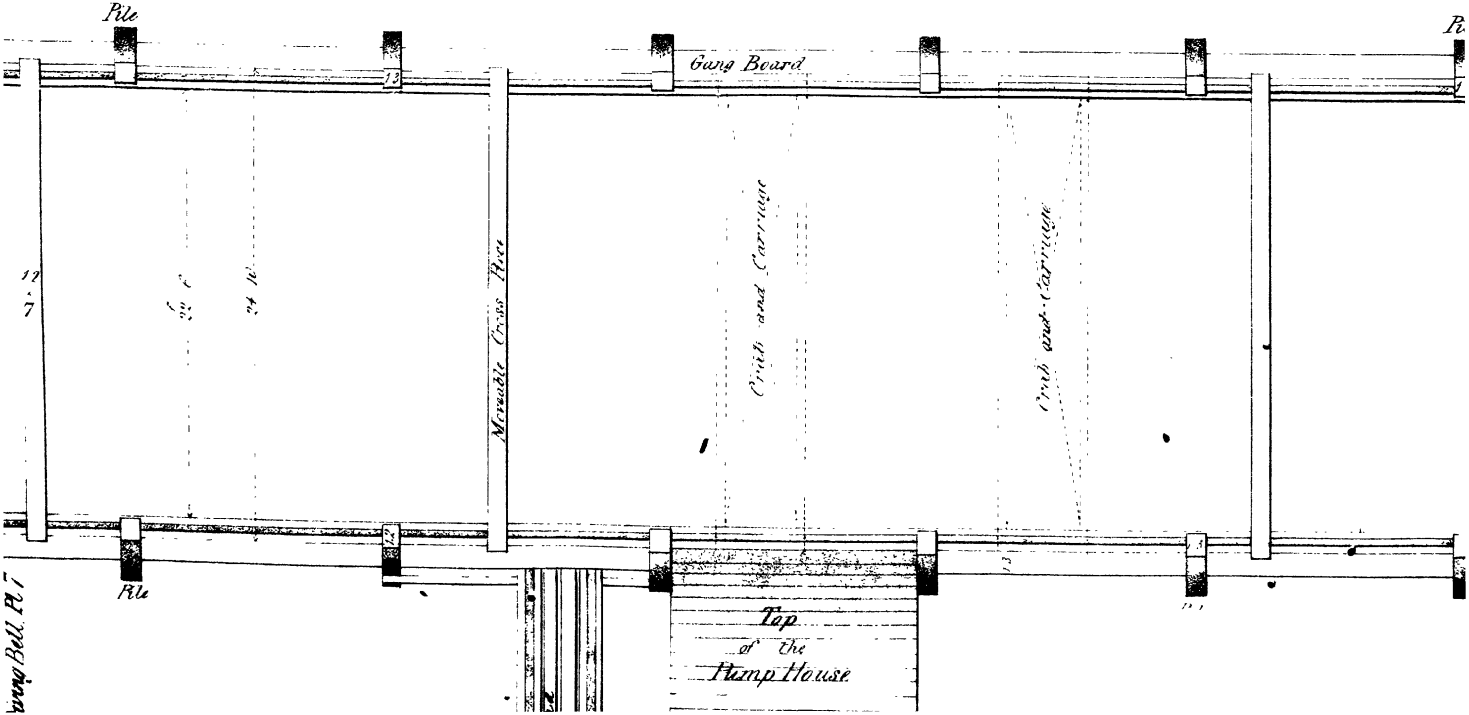


Diving Bell Pl 6.

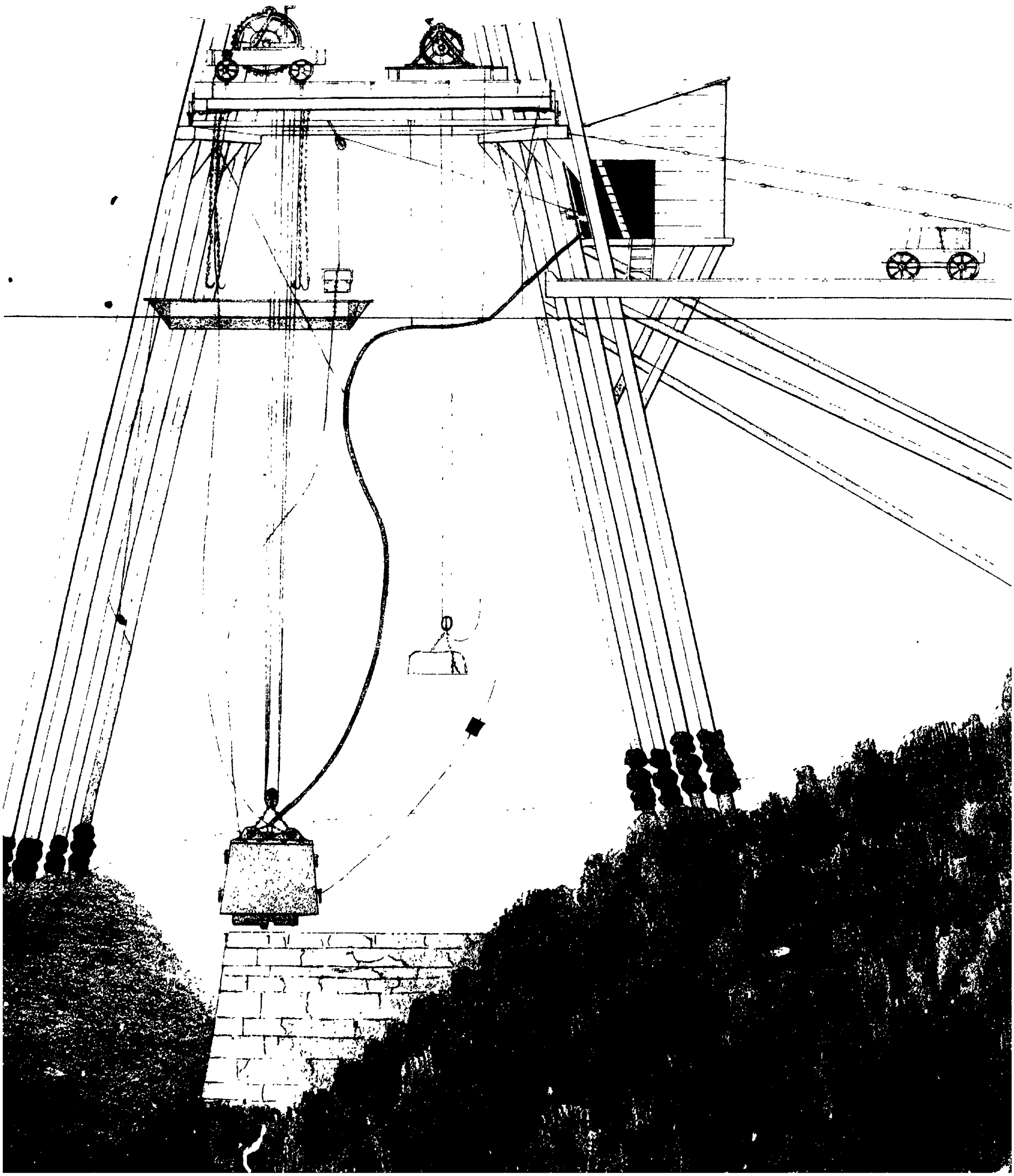


# Plan

of the top of the Stage erected for the use of the Diving Bell's



Elevation of a Diving Bell and Machinery with a View of part of the Stage from which the Bells were worked and a Section shewing the nature of the Foundation of the Pier at Hobbs Point



## *Of the Stage.*

*Diving-Bell, plate* 7.—The stage from which the diving-bells were worked embraced the whole *width* of the pier-wall, erected with piles from sixty to seventy-five feet long, and from fourteen to fifteen inches square: they were pointed and shod with iron at the bottom, and had also large flat stones bolted to them, by which means they were more easily fixed in their proper places. The outer and inner rows were twenty-three feet six inches apart in the clear at the top. The tiles battered about one-fifth, and were placed from ten feet to twelve feet from each other. The string-pieces upon which the rail-road was laid, were about forty feet long (each length), and from fourteen to fifteen inches square, secured to the piles by screw-bolts and nuts. The string-pieces were supported by strong cleats under them, which were nailed and screwed to the piles; they were also further secured by an iron band. The level of the rail-road on the stage was nine feet six inches above high-water spring-tides. A gang-board, fifteen inches wide, was fixed on the outside of the string-pieces, for the workmen to walk on. Strong struts were fixed against the outer and inner row of piles, and the stage was secured to the shore by iron chains, which could be tightened by screws when required. The front and back parts of the stage were connected together by cross pieces of timber (fourteen inches × seven inches), bolted down to the string-pieces; underneath them cleats were nailed, for the purpose of steadying the stage, and keeping it apart: these cross-pieces were occasionally shifted; one was always placed at each end of the part of the work where the diving-bell was employed, a space generally of from thirty to forty feet in length. At different parts, along the stage, sheds were erected, in which the air-pumps were placed, and also a small windlass, by which the box containing the rock and shingle, that had been excavated by the workmen employed in the diving-bell, was drawn up, and the contents emptied into a barge stationed to receive it. By similar means spawles and mortar were lowered down to the masons who were building in the bell. A boat was always in attendance, in which there was a supply of mortar and small stones, &c. kept in readiness, and also a labourer to empty and fill these boxes. A small line was attached to them, by which means they were pulled into the bells by the workmen. The floors of the pump-houses were about six feet above high water; and as the tops of them abutted against the string-piece of the stage, and were level with it, their roofs were very useful for laying many small articles on required by the workmen employed on the stage. I forgot to metion, that the mortar-box had a cover to it. The roads by which the large stones were brought from the shore to the stage, were formed by two baulks about fourteen inches square, laid parallel to each other, three feet apart, having a gentle slope towards the front wall of the pier, by which means the truck upon which the stone was placed was easily pushed forward by one man, as a rail-road was laid upon the baulks; one end of them rested upon a strong piece of timber, which was spiked to two of the inner row of stage piles, and the other end on the bank on the shore: the centre was supported by uprights. These roads were from sixty to eighty feet long: a piece of wood was nailed across the outer end of them, to prevent the truck from running over.

## *Of the Bell Vessel.*

The diving-bells at Hobbs' Point, were at first worked from a schooner of about 120 tons: a stage having been erected across her deck projecting over each side, from thence the bells were suspended from crabs placed on the stage. The air-pumps were fixed on the deck of the vessel. This mode of working the bells was attended with many inconveniences, particularly from the great rise and fall of the tide, by which the diving-bells could not, without much difficulty and constant attention, be kept working in the same place; therefore, after clearing in a rough manner the general outline required for the area of the pier-walls, this manner of working the bells was discontinued, and the stage already described erected.

## *Of the Dredging Boat.*

The greatest part of the mud, and a large quantity of small shingle, was removed by a dredge, worked from a flat-bottomed barge, forty-eight feet long, thirteen feet wide, and three feet deep; across the gunwale a platform of three-inch plank was laid, and on it a cast-iron crab was fixed, near which a small derrick was raised seven or eight feet high. The pole to the end of which the dredge was attached was thirty-seven feet long: when it was lowered for the purpose of scraping up the mud, shingle, &c. the pole was placed alongside the barge, the top inclining forward, and secured to the gunwale by a rope halter fastened to a ring-bolt fixed on the inside of the vessel. A small chain was fixed to the front of the dredge, which ran through a block fastened to the top of the derrick, from thence communicating with the crab, by which the dredge was drawn along the bottom, and raised out of the water, and then emptied (by means of a rope attached to it with a hook) into the barge. Four men were required to work the dredging vessel, viz. two at the crab, one at the dredge to keep it in its proper position, and one to empty it, and level the rubbish, &c. in the bottom of the barge.

### *Of the Tin Tubes and Borers used in Blasting Rock under Water.*

The pitching borer, so called from its being the first used, was a round iron bar, two inches and a quarter in diameter, and about two feet long; with this tool a hole was bored about six inches or eight inches deep; a smaller borer of two inches in diameter was then used to bore it to the depth required, which was sometimes four or five feet. The powder to charge the mine was put into a cylindrical tin case, generally from ten inches to one foot long, but varying in length according to the quantity of powder required. A small tin tube half an inch in diameter (outside) was inserted, and soldered into the case holding the powder, about six inches down in the inside of it; the top of the case was covered with a piece of tin, through which the small tube was put. Great care must be taken that both the tube and case are well soldered, that the powder should not get wet. The tin tubes were made in lengths about four feet six inches each, the tops of them splayed a little (like a funnel), the diameter of which was one inch and an eighth; into it the next length of tube was inserted, being carefully puttied round to keep out the water; a sufficient number were used, so that the last should rise a little above the surface of the water. The mine was fired by dropping a small piece of red hot iron (which was pointed at the end) down the tube.

### *Description of the Tools used in the Diving-Bell.*

The tools used by the masons employed in the bell building were:—

1st. Two setting bars, the lower ends of which were curved up, which enabled the workmen to move the large stones with greater facility than they otherwise could, in the confined space they worked in.

2nd. A spawl-driver, the handle of which was three feet long, of one inch and a quarter diameter rod-iron, with a head at the end of it, three inches and a half wide: the use of the tool was to drive down the small pieces of stone between the joints of the large ones, which from the depth of water could not be so well done by a common mason's hammer.

3rd. A sledge hammer, or maul.

4th. A narrow plate of iron, about one inch and a half wide, one-tenth thick, and two feet nine inches long, with a handle: this was used to work the mortar in between the vertical joints.

5th. A short boat-hook, about four feet long.

6th. A shovel with a short handle.

7th. Two signal-hammers.

8th. A pair of lewises.

9th. Two chains, a large and a small one, a swab, a piece of chalk, a trowel, and foot rule.

The miners in the bell employed excavating shingle, rubble, and rock, required the following tools, viz.:

1st. A crow-bar, three feet long.

2nd. A miner's pick with a short handle.

3rd. A shovel.

4th. A sledge-hammer.

5th. Two signal-hammers.

6th. Several gads of different lengths and sizes, a swab, and a piece of chalk. Tin tubes, powder, and borers, were taken down by the workmen when wanted.

### *Manner of Working the Diving-Bells.*

The bells were at first, for a few months, worked from a vessel of about 120 tons, but from its being found very inconvenient, a stage (as before described) was erected. On the top of which was a strong wooden carriage, mounted on four iron wheels, traversing on a rail-road from one end of the stage to the other, (which extended the whole length of the front wall of the pier, 200 feet); on this carriage another rail-road was laid, on which was placed a crab and carriage, and to it the diving-bell was attached: by this means it could be moved wherever required, with the greatest ease. In the summer, the bells were employed from five o'clock in the morning till seven o'clock in the evening: the remainder of the year, from daylight till dark. The principal directions necessary to be given for carrying on the work in the bells, were communicated by the men employed in them to the superintending foreman (who was constantly stationed on the stage), by striking the side of the diving-bell with the signal-hammer a certain number of strokes, each having a particular signification, of which the following is an explanation, viz.:

*One* stroke, signifies that they require more air.
*Two* — to let the bell remain as it is.
*Three* — to raise it.
*Four* — to lower.
*Five* — to move the bell to the front of the wall.
*Six* — to the back.
*Seven* — to the right.
*Eight* — to the left.

All other communications were made by writing them with chalk on a small board painted black, to which a line was attached, reaching from the bell to the stage, which was pulled up by the workmen, when they wished to send up a message: there was a small chain, about five or six feet long, fixed to the lower end of this line, or otherwise it would soon have worn out, by rubbing against the bottom edge of the diving-bell when drawing the message-board up and down.

A carriage and crab similar to those used for the bell was employed for lowering the large stones to the workmen, and the small stones and mortar were sent down to them in a small box. A labourer was stationed in a barge, who attended upon two bells, either to receive what the miners excavated, or to supply the masons with materials.

bolted together. The highest part of the front wall is sixty-two feet from the foundation to the top of the coping, which is of granite two feet thick. The following quantity of work was executed with the diving-bells, viz. 62,062 cubic feet of masonry built; 767 cubic yards of solid rock, excavated and removed; and 3043 cubic yards of rubbish and shingle. From two to four bells were in use for four years. By regular weekly returns which were kept of the time the diving-bells were employed, and also of the quantity and quality of the work done with them, I find upon an average that fifty cubic feet of limestone masonry was built in each bell per diem, three-fourths of a cubic yard of solid rock excavated and removed, and four cubic yards of rubbish and shingle, allowing twelve hours for a day's work. The time of the whole of the bells were employed was equal to 31,006 hours for *one* bell, viz. 16,065 hours excavating rock, rubbish, and shingle, and 14,941 hours building. The average time the diving-bells were prevented working, on account of the weather, for the four years they were in use, was four days during each winter month, and one day and two-thirds in the summer months. The expense of each bell for *wages alone* for the workmen, upon an average, was 1*l.* 10*s.* when employed in building, and 1*l.* 6*s.* when excavating, each day, allowing the bell was in use twelve hours: to the above sum must be added, the expense of staging, machinery, gear, rope, oil, &c. &c., which was very considerable, and which must depend in a great measure upon localities.

The lime used was Aberthaw, in the proportion of two of sand to one of lime, measured in lumps as taken from the kiln, slaked with cold water and sifted.

### *General Observations on Bell-Work.*

From the improvements made in the construction of diving-bells, and the facility with which the workmen can be furnished with an ample supply of air by means of the air-pump, any description of work may now be executed by their means, with very little difficulty or danger. Having for the space of four years been constantly in the habit of going down in the diving-bells employed in the erection of the landing wharf at Hobbs' Point, Milford Haven, for the purpose of inspecting and measuring the work in progress, I am fully satisfied, that building may be performed under water with an equal certainty as above; but the greatest possible care must be constantly paid in carrying on the work;

to ensure which, it is essentially necessary that a very steady attentive man should have the entire direction of all the people attached to the diving-bells, who will also pay the strictest attention to all signals made by the workmen employed down in them, and by whom the whole of the machinery, gear, &c. (*particularly the fall*) should carefully be examined every morning, and a written report given that he had done so to the officer superintending the work. The greatest inconvenience experienced by the men working in the bells, was the pain produced in the ears from the pressure of the condensed air on the drum, which occasionally, when in very deep water, brought blood from them, and also from the nose; this, however, rarely happened, and as a proof that they did not suffer any very great inconvenience, *one* man only ever quitted bell-work from choice, and several were employed in them from the commencement to the completion of the work, a period of upwards of four years. The workmen in the diving-bells always wore thick flannel frocks and breeches, and high mud boots well greased, and most of them flannel or worsted caps. From the depth of water at high tide (especially during the winter months), and from the heavy rains, it was so muddy that candles were obliged then almost constantly to be used, when it was found necessary to have an additional man at the air-pump. From the greatest attention to the signals made by the workmen employed in the diving-bells, and a constant examination of the machinery and gear, not the most *trifling accident* occurred during the whole period the bells were in use; but I feel it my duty to state (as a warning), that a most serious one would most probably once have happened, had the bell not been in very deep water at the time, in consequence of the small line attached to the message-board getting between the cheeks and sheave of the lower block, and thereby for a short time jamming the fall, and as the bell was lowering down, several yards of it became slack; therefore, when the line got disengaged from the block, which it soon did, the diving-bell suddenly fell at least ten feet; the jerk thereby occasioned was not felt much, as the bell most fortunately was then in very deep water, otherwise it would most probably have broken the fall, and proved fatal to the two men that were in the diving-bell. To prevent the possibility of this happening again, I immediately had three straps of leather, about two inches wide, nailed across the cheeks of all the lower blocks, which I recommend always being done.

The foregoing observations on bell-work, claim the merit only of giving a detailed and faithful description of the means adopted in the erection of a landing wharf at Hobbs' Point, Milford Haven, by the use of diving-bells; which work was commenced on the 16th December, 1829, and completed on the 3rd January, 1834, under my superintendence.

(Signed) W. J. SAVAGE,
Captain, Royal Engineers.

Pembroke,
May, 1836.

As officers may be often thrown into situations where, although advisable to use a diving-bell, it may be impossible to procure a cast-iron bell of sufficient dimensions, the following account of a wooden bell, extracted from the 'Transactions of the Institution of Civil Engineers,' may perhaps prove useful.

*Description of a Wooden Diving-Bell employed by Mr. Rendel in the Construction of the Lary Bridge, near Plymouth.*

The internal dimensions of the bell were five feet six inches in length, four feet six inches in width, and five feet in height; the sides, ends, and top, were made of two thicknesses of inch-and-half well-seasoned elm board; the inner case was constructed with its joints parallel to the top and bottom, or mouth of the bell, whilst those of the outer case were vertical, or at right angles to the inner joints; the top joints were crossed in the same manner as the sides; all the joints had a slip of flannel saturated in a composition of bees-wax laid between them, and were dovetailed together, and set as close as possible, by means of screw-clamps, &c.; the sides were rabbetted to the end, and the internal angles strengthened with brackets. The whole surface between the inner and outer case was covered with double flannel, saturated as just described, and was then connected together by a number of wooden pins dipped in tar, and tightly driven: the top was perforated with six holes, of six inches diameter each, in which were fimly fixed a corresponding number of strong lenses set in white lead; a hole of three inches diameter was made in the centre, in which was fixed a brass pipe with a screw to attach the air-tube: four hoops of wrought iron, two internal and two external, were screw-bolted together, through the sides and ends of the bell; internal and external cross-lacings were also screw-bolted to those hoops, and to the sides and top of the bell; in these lacings, the chains by which the bell was suspended were fixed in strong iron eyes, which passed through the top of the bell, and were rivetted to the inner lacings. All the screw-bolts were driven with tarred oakum, and every precaution was taken to render the whole air-tight. The bell, thus finished, weighed about thirty hundred weight; but it required from five to six tons and a half to sink it, and overhaul the ropes by which it was suspended: cast-iron plates, from one inch and three quarters to two inches in thickness, were therefore hung externally round its sides and ends, till it was sufficiently loaded to sink with steadiness in about twenty-five feet water. The bell was provided with two moveable seats and a foot-board for the drivers, and at top long boxes were fixed in which their tools were kept; it was provided with air by a double-acting force-pump, the cylinders of which were seven inches diameter in the clear, making a fourteen-inch stroke. This pump was generally worked by four men, and made on an average, according to the depth of the water and the run of the tide, about eight double strokes in a minute.

This bell was mounted and worked upon a carriage and platform, similar to that described by Captain Savage.

(Signed) W. DENISON,
Lieutenant, Royal Engineers.

## XVII.—*Extracts from a Report on the Copper Pontoons used in the Neapolitan Service, in* 1805, *with Remarks on the Inefficiency of all open Pontoons of the common rectangular Form, for the Passage of rapid Rivers, by* C. W. Pasley, *Colonel, Royal Engineers, &c. &c.*

Being attached to the British army under the command of Sir James Craig, which landed at Castellamare, near Naples, in 1805, having then the rank of Second Captain, I was sent towards the Neapolitan frontier, in the month of December of that year, to make a report on the passage of the river Garigliano, assisted by Lieut. Macleod, who was placed under my orders for that purpose.

My instructions, drawn up by Captain Lefebure, the commanding engineer on that expedition (whose memory deservedly stands high in the corps), particularly specified,—First, that I should examine attentively the construction of a bridge proposed to be thrown over that river by the Neapolitans, and report how far it might be considered as a safe passage for an army, with its cavalry and artillery, especially if the river should be liable to floods.

Secondly, that I should examine minutely, and reconnoitre the river in the neighbourhood of the Neapolitan bridge, noting the fords, if any, and also the most convenient places for the construction of additional safe passages for troops, to be formed by making use of such means as the neighbouring country could afford, which I was to ascertain and report upon.

On my arrival at the Garigliano, on the high road from Capua to Terracina, I found a Neapolitan pontoon train in readiness to form a bridge across the river, where the only communication at that time was by a large ferry-boat. I took drawings of every part of these pontoons, and of their carriages and stores, from which models have since been made that are now preserved at Chatham. They were interesting to me, from being the first complete pontoon equipage that I had ever seen.

A few days' observation convinced me of the inefficiency of these pontoons; and as they were evidently a copy of the old French copper pontoons, and agreed also very nearly in their external form and capacity with the old English tin pontoons,* which I trust are for ever abolished in our service, the following extracts from my Report may prove, that no small open pontoons of the common rectangular form can be depended upon, for the passage of any rapid river such as the Garigliano.†

I had not, at that time, experience enough to judge of all the disadvantages of these pontoons, which, though under the charge of Lieutenant Don Nicola Catalemme, a very active, zealous, and intelligent officer, with ample means, required nearly seven hours for the formation of a bridge of 170 feet, which bridge was scarcely finished when the state of the river required it to be dismantled, in order to prevent it from being swept away by the current: but I saw enough to convince me of the total unfitness of the Neapolitan pontoons to form a safe and constant passage for troops over the Garigliano; and, therefore, I proposed that they should be removed, and that a bridge of the large fishing-boats used on that coast, and known by the name of Paranzelle, which I went to Gaeta to examine, should be formed over the Garigliano: and, agreeably to my instructions, I gave in a detailed project for a bridge of boats of that description, of which the drawings are still in my possession; but I do not think that this would be interesting.

My remarks on the Neapolitan pontoons may, however, be useful, as they may assist in eradicating the prejudices in favour of our old English, or rather Dutch, pontoons, which I believe even now are not without their partisans, in spite of their failures on the Guadiana‡ and on the Garonne; the latter of which,

* The large English tin pontoons are somewhat longer, but not quite so deep.

† The inefficiency of this sort of pontoon is so well understood in the French service, that the author of the "Guide du Pontonnier," after having merely stated the dimensions of the French copper pontoon of the last pattern, dismissed it without further notice, after remarking, "that this pontoon, sufficient for secondary rivers, had not stability enough on great rivers, such as the Rhine. Besides which it had been found, that its form and construction did not admit of its being employed for the passage of troops." If so, what was it fit for?

‡ "Two different descriptions of bridges (one of which was a pontoon bridge), for the conveyance of artillery and stores, were completed over the Guadiana, on the 23rd of April, 1811, and the following day was fixed for the investment of the place. The weather had settled apparently fine, and every thing promised well; but, such is the uncertainty of military operations, and on such uncontrollable causes does success frequently depend, that, from the fall of distant torrents, the river swelled perpendicularly in the night seven feet: before the bridges could be taken up they were carried away, and the materials composing them floated down the stream, so that, on the 24th, the army, far from being able to act offensively, had lost all its communications with Portugal.

"In a few days, by great exertions, another bridge was prepared, and the place was invested." (Jones's Account of the War in Spain, Portugal, and the South of France, vol. i. chap. 11.)

damaged or carried away a part of it; and, although the King of Sardinia has expressed a particular desire to pass over it, the pontoneers still think it too hazardous to attempt putting it together.

*State of the Bridge, &c.*—The bridge will be again completed as soon as the weather and state of the river will permit; but I judged it unnecessary to defer any longer sending this Report, the same circumstances being likely, on future occasions, to cause it to be broken up; so that, although I do not hesitate to vouch for its being, at certain times, a safe communication, I cannot certify for its being an uninterrupted one.

*Proposal for an Uninterrupted Communication across the River.*—If therefore an uninterrupted communication be required, I should beg leave to recommend a bridge to be formed of the fishing-boats called *Paranzelle*, nine of which will be sufficient for this part of the river. One of this kind, we are informed by the peasants, was established here by the French, which remained entire for a whole winter, whilst a Neapolitan pontoon bridge in the same situation, was, at another time, carried away, and entirely destroyed, the pontoneers having neglected to take it to pieces, on a sudden rising of the river.

*Other Means of Communicating across the River.*—The abovementioned boats can go up the river as far as Ponte Corvo; besides which there is a kind of flat-bottomed boat, called *Sandali*, used for floating down timber from the mountains, both of which, from their dimensions, are capable of transporting the heaviest artillery. A kind of punt is used as a ferry, which is capable of supporting an equal weight with the pontoons; and artillery might be passed on this, but of course with considerable delay and interruption.

Lieut. Macleod, who delivers this, will, at the same time, present you with a sketch of the position of the bridge, and will give you further explanations.

(Signed) C. W. PASLEY,

Captain, Royal Engineers

## XVIII.—*Investigation of the Position of the Horizontal Axis of a Self-acting Sluice-Gate.*

The following notes are extracted from an article in the 'Mémorial du Génie,' and may perhaps be found to convey useful hints to officers employed in the civil branches of our service.

Captain Petitot, the author of the article in the Mémorial du Génie, introduces the subject by a brief account of the various kinds of sluices at present in use, and states the difficulties which occur in working them, more especially when they are employed to give a passage to the surplus waters of a river subject to sudden floods. In cases of this kind, where the flood comes on rapidly, an immense deal of damage may be done before the sluices can be got to act, and it would therefore be most desirable to devise some kind of self-acting-sluice, which should always keep the waters up to a certain height, and yet upon any increase of this should give way, allow the flood-waters to pass, and return to its former position as soon as the necessity of its being open should cease. Captain Petitot proposes the following problem, the solution of which would accomplish this object.

Problem.—A sluice acts as a dam to a stream, and is kept in a vertical position between two stanchions, by means of a horizontal axis upon which it turns. The water, both above and below the sluice, operates to turn it on its axis, which is placed at a certain distance from the bottom of the gate. The friction of the trunnions in their sockets tends to prevent any motion: it is required to determine the conditions of equilibrium of this sluice, and to form a general equation, into which the height of the water above and below the sluice, and the height of the trunnions or axis above the level of the apron, shall enter, in such a manner, that any two of them being given, according to the circumstances of the cases, the value of the third may be determined, so that the gate being in a perfect state of equilibrium, the least effort may put it into motion.

Since the sluice is required to turn on a fixed axis, it will be sufficient to establish the conditions of equilibrium, if we express the sum of the pressures which have any tendency to make it turn in one direction, and make them equal to the sum of those pressures which operate to turn it in a contrary direction, or to retain it in its place.

Let then $h$ = the height of the sluice above the apron.

$b$ = its breadth.

$d$ = the distance from the apron to the position of the axis of the trunnions.

$H$ = the height of the water above the apron at its maximum, just before the sluice should open.

$x$ = the height of the water in the apron below the sluice at the same time.

$p$ = weight of sluice.

$r$ = radius of trunnions.

$f$ = ratio of friction to pressure.

$g$ = specific gravity of water.

We have then, for the sum of the pressure on the upper part of the sluice, tending to turn it,

$$\frac{g\,b}{6}(h-d)^2(3\,H-2\,h-d) \qquad \text{(A)}$$

for the sum of the pressure on the lower part of the sluice, tending to keep it steady,

$$\frac{g\,b}{6}d^2(3\,H-d) \qquad \text{(B)}$$

for the sum of the pressure of the water below the sluice, tending to open it,

$$\frac{g\,b}{6}x^2(3\,d-x) \qquad \text{(C)}$$

and lastly, for the friction, the expression

$$fr.\sqrt{g^2\,b^2\,(2\,H\,h-h^2-x^2)^2+4\,p^2} \qquad \text{(D)}.$$

The equation of equilibrium will be found by making the expressions A and C = to those B and D, and it will be, when reduced,

$$\frac{g\,b}{3}\Big\{x^2(3\,d-x)+h^2(3\,H-2\,h+3\,d)-6\,h\,d\,H\Big\}\mp$$

$$\mp fr.\sqrt{g^2\,b^2\,(2\,H\,h-h^2-x^2)^2+4\,p^2}=0.$$

Where the double sign of the expression for the friction comprehends the cases where the sluice is ready to turn up or down stream, in which case the friction acts in contrary directions.

When these sluices are to be applied to a river where it is necessary to keep the water up to a certain height, for the sake of machinery established on the stream, it is necessary, after having determined the position of the apron, to fix the height and length of the sluice in such a manner, that during the driest seasons the pond above the sluice should always be of sufficient depth; at the same time the outlet must not be diminished, to provide against accidents by floods. The sum therefore of the lengths of the sluices should be equal to the breadth of the river, and their height to that of the water necessary for the works, diminished by the depth of the low-water section of the river. As, however, it is not necessary that the sluices should open with the slightest increase of water beyond what is required for the works, $H$, in the equation of equilibrium, may be taken as the height of the highest water the works will bear, or which will not cause a flood, this height being, in all cases, calculated from the surface of the apron. As for the height $x$ of the water below the sluices, this will be equal to the thickness of the film of water passing over the sluice, augmented or diminished, according as the section of the river below is smaller or larger than that above the sluices. This, however, will always be best determined by actual experiment. The value of $H$ and $x$ being then determined, and substituted in the general equation, the value of $d$, or the height at which the trunnions should be fixed, in order that the least amount of pressure may turn the sluice, is easily found.

$$d = \frac{x^3 - h^2(3H - 2h) \pm \frac{3fr}{gb}\sqrt{g^2b^2(2Hh - h^2 - x^2)^2 + 4p^2}}{3(x^2 + h^2 - 2Hh)}$$

but as the term $4p^2$ has to be multiplied by $\frac{9f^2r^2}{g^2b^2}$ it will become so small a quantity as to be safely neglected, and the equation then becomes

$$d = \frac{x^3 - h^2(3H - 2h) \pm 3fr(2Hh - h^2 - x^2)}{3(x^2 + h^2 - 2Hh)}$$

In this case the positive sign is to be used, as the sluice only turns down stream.

In practice, the bottom of the sluice should be bevelled, having only a small portion left flat, and this should be shod with iron.

The trunnions turn in brass boxes or sockets, and a ledge on the stanchions prevents the sluice turning beyond the horizontal direction, or indeed beyond any angle at which it may be thought desirable to stop it.

Experiments were made to determine the qualities of this sluice, and these proved very satisfactory: it not only turned over when the water rose beyond the height calculated upon, but as soon as the surplus water had passed away it regained its position; this, however, was facilitated by making the lower portion of the sluice rather heavier than the upper.

Experiments were also made with the view of ascertaining whether a deposit of gravel above the sluice would prove a serious impediment to its action, and in all cases it was found that the only effect was to delay the opening a little, and to require a trifling additional head of water.

W. DENISON,

Lieutenant, Royal Engineers.

## XIX.—*On Mr. Kyan's Process for the Preservation of Timber from Dry-Rot, with a Description of the Tank erected for that purpose in the Royal Arsenal, Woolwich.*

Woolwich, December 1836.

THE discovery by Mr. Kyan of a very simple process, by means of which Timber may be preserved from the effect of Dry-rot, and, at the same time, permanently seasoned in a few weeks, having undergone an ordeal of several years, without having failed in any of the trials to which it has been subjected, would appear to be highly deserving of extensive adoption in the Engineer Department.

The Commanding Engineer at this station, taking this view of the subject, applied for, and obtained permission from the Master-General and Board,* to have a tank established at the Engineer yard in the Arsenal.

The Anti-Dry-Rot Company (who have purchased Mr. Kyan's patent), on being applied to, preferred erecting the tank and supplying the solution themselves,† leaving it to the Department to give in a statement, from time to time, of the quantity of wood prepared, to be paid for at the rate of 20*s.* per load of 50 cubic feet. ‡

They immediately sent down the frames of two tanks, made of four-inch Canadian pine-plank, with the bolts, &c. complete, and ready for putting together.

The large tank was sixty feet long, eight feet wide, and six feet deep in the clear. *Vide fig.* 2.

* See Commanding Engineer's letter to the Inspector-General, Appendix No. 1.

† See Anti-Dry-Rot Company's letter, Appendix No. 2.

‡ This mode appears to have been adopted to ensure the proper construction of the tank, as well as from the number of Ordnance departments within the Arsenal who might have access to it.

The Company are, I understand, quite ready to grant licenses to other Ordnance stations on the same terms as private licences, viz. 5*s.* per cubic foot, internal content of the tank, they supplying the corrosive sublimate at the market price, having a manufactory for that purpose, to secure its being genuine. In estimating for a tank, therefore, the expense of the licence must be included, as well as a demand for the corrosive sublimate, at 4*s.* per lb. (the present market price), $1\frac{1}{2}$ lb. of corrosive sublimate being an average consumption for every load of timber, of fifty cubic feet, saturated. The strength of the solution being in this calculation, 1 lb. of sublimate to fifteen gallons of water.

An hydrometer will also be required.

In a tank of such large dimensions, it was deemed necessary to take great precautions, to prevent accidents, when loaded, from the upwards pressure of the timber wedged down in the tank, amounting of course to the difference of the specific gravity of the timber and that of the solution.

The mode adopted was as follows: an excavation was made of sufficient dimensions to receive the tank, and admit of a nine-inch brick wall being built round it.

A foundation of concrete, one foot six inches thick, was then laid; upon this a course of bricks laid flat in cement; then a second course, or edge, in cement also, leaving channels in it for the centre longitudinal beam (*c*), and three transverse beams or bands (*b b b*), so that whilst they rested on the first course of brick-work, the bottom of the tank rested on the upper course. *Vide section, fig.* 3.

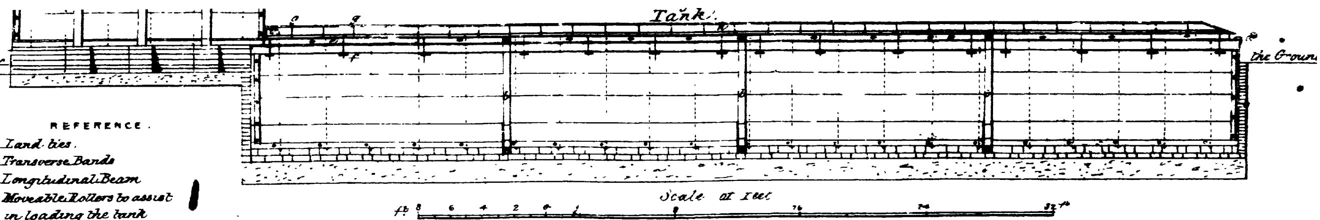
The foundations being ready, the tank was put together on temporary supports, ready to be lowered into its place by screw-jacks, as follows:

The bottom of the tank was first put together, consisting of two four-inch planks on each side of the centre beam (*c*): the whole of these planks had square joints, which were payed over with a mixture of tar, white lead, and whiting, on which a layer of split rushes was laid, to act as a caulking; the round bolts, seven-eighths of an inch in diameter, with a head or shoulder, and plate three inches and a half square at one end, and a similar plate, with a nut and screw at the other, were then passed through the centre of the planks and screwed up tight.

Similar bolts were then passed through the bottom vertically, two inches from the edge all round, to receive the planks of the sides and ends, which were put together in the same manner, having a six-inch oak capping on the top, projecting two inches inside, through which the bolts passed; a two-inch piece of pine was then pinned on to cover the heads of the bolts and nuts.

By these precautions the tank was rendered water-tight, and the iron-work prevented coming into contact with the solution, *two most essential desiderata.* To give additional strength, the sides were made to project beyond the ends, and bolts of a similar description passed outside horizontally, and secured with nuts and screws, or a continuous plate or strap of iron, instead of the small plates before described.

The transverse frames or bands were then fixed, and the tank was lowered into its place, leaving the top about one foot above the level of the ground.




REFERENCE.

aaa. Land ties.
bbb Transverse Bands
cc Longitudinal Beam
ddd Moveable Rollers to assist in loading the tank
ee Slip of Inch Pine on which the roof rests
ff Iron hold fasts to secure ee and to enable it to be taken off when loading or unloading the tank.
gg Shew the divisions in the Roof to facilitate its removal.
hh Iron Straps to lock up the Tank and Cistern
ll. Two inch Plank to cover over the heads of the bolts Plates, & Nuts, passing through the sides and ends, a common Wooden moveable Pump is used for pumping the Solution out of the Tank into the Cistern, when the Tank is to be unloaded

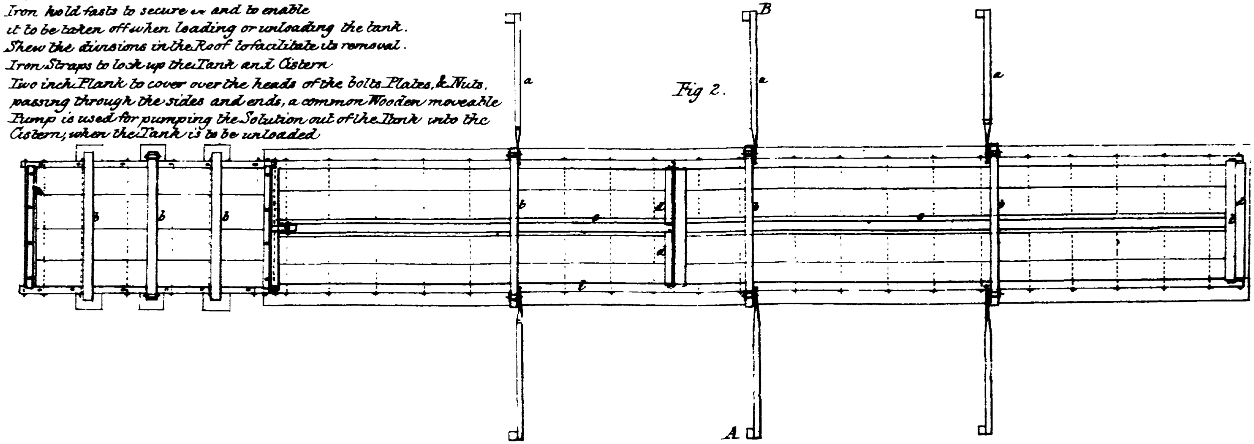
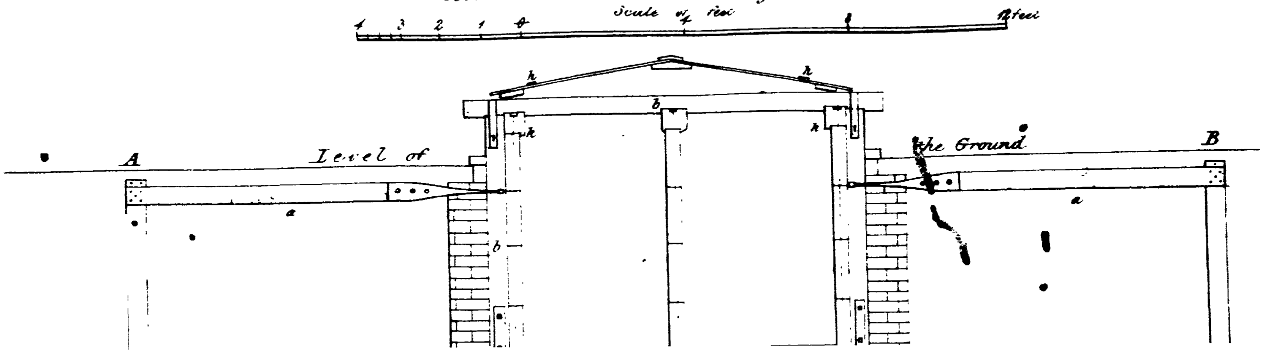



Fig 2.

Section on the line. _ A.B. Fig 2.



A nine-inch brick wall was then built up round it in cement, leaving half an inch all round for a grouting of the same material.

These precautions having been taken, to prevent the tank bulging or bursting, a counter precaution was adopted, to prevent its collapsing, by three land-ties (*a a a*) *fig.* 2, placed on each side, each being connected at one end to one of the bolts passing through the side-pieces, and at the other to a small pile. *Vide section, fig.* 3.

The tank was then divided into four compartments,* by a longitudinal partition let into a groove in the longitudinal beam in the bottom, and by a transverse one at twenty-five feet from one end.

The bolts of these partitions did not go through the bottom of the tank; in other respects they were put together like the remainder of the tank.

The cistern having been put together like the tank, was raised on a foundation of concrete and masonry. *Vide fig.* 1.

The construction of the smaller tank,† fifteen feet long, is described in the drawings of the Company's prospectus, excepting that its cistern was placed in the same position as that of the large tank, which gives free access to the tank in loading and unloading.

The mode of securing the timber to be saturated, called loading the tank, and the mixing the solution, are stated in the prospectus: they are extremely simple; the only thing to be attended to is the wedging down the timber before the solution is admitted, which is done by props placed against the transverse beams or bands, wedged tight longitudinally, so as to be eased or removed with facility when required. ‡

* The dividing this tank into four compartments, appears to me to have done away with the necessity of so many precautions being used to prevent accidents; one or two additional transverse beams would have answered the purpose, and are indeed much required, as in two of the divisions there is but one transverse beam, and the capping (*k k*) is obliged to be used in wedging down the timber to be saturated, when in short lengths.

† This tank was stated to be for canvass, cordage, &c.; it is, however, extremely useful for short pieces of timber.

It is perhaps necessary to state, that the solution in which oak has been saturated is discoloured, and not generally used for canvass, &c. Pine does not discolour the solution.

‡ Notwithstanding the precautions here adopted in forming permanent tanks, an old rum, beef, or pork cask, as a cistern, and a rude trough formed out of a log like a canoe, or any water-tight trough, as a tank (so that no iron or other metal is visible in the interior), will answer the purpose. A few pounds of corrosive sublimate, and an hydrometer, are the only articles of importation required.

In order to give confidence in the efficacy of the process, I have selected one or two extracts from the lectures of Professor Faraday and Dr. Birkbeck, on the subject.

Professor Faraday, in his lecture at the Royal Institution, February 22nd, 1833, after explaining that the preservation of the wood arises from a chemical combination, which takes place between the corrosive sublimate and those albuminous particles, which Berzelius and others, of the highest authority, consider to exist in, and form the essence of wood, which being the first parts to run to decay, cause others to decay with them; also, after witnessing various trials, extending to five years in the fungus-pit at Woolwich, in all of which the prepared timber and canvass came out perfectly sound, whilst the unprepared were decayed, gives his opinion, "that the process would be found effectual in preserving timber, &c., and that the improvement would be so great as fully to justify its extensive application."

Dr. Birkbeck, in a lecture on the same subject, delivered at the Society of Arts, Adelphi, December 9th, 1834, after explaining the causes of decomposition in vegetable substances, states, "that Mr. Kyan's process acts on vegetable in the same way as tanning does on animal substances." He also quotes the trials in the fungus-pit at Woolwich, and concludes with the following: "This is a probation which must be considered quite sufficient to decide the question."*

The memorandum also of Colonel Sir John May, K. C. B., Inspector-General, Royal Carriage Department, at Woolwich, as well as the report of Captain Hardinge, Deputy Inspector of that Department, dated 25th March, 1835, published in the Report of the Committee appointed by the Lords Commissioners of the Admiralty to investigate Kyan's Patent; together with the Second Report of Captain Hardinge, after eighteen months longer trial, dated 28th September, 1836; copies of which I have obtained, by permission of the Master-General and Board, are herewith annexed; they are most satisfactory. *Vide Appendix, No.* 3.†

* Both these lectures are published by John Weale, 59, Holborn; and from the high characters of their authors, are most interesting and conclusive. I can state, that Professor Faraday, up to the present time, has seen no reason to alter his opinion of the efficacy of this process. 1837.

† The ship Samuel Enderby, of 420 tons, built at Cowes in 1834, in which all the timbers, sails, and ropes were prepared according to Mr. Kyan's process, and now absent in the South Sea fishery, will, on her return, be a good specimen of the effect both of the durability of the materials and health of the crew.

The expediency of the adoption of this process by our department, will be at once evident, by an attentive perusal of Colonel Harding's letter, before quoted. *Vide Appendix*, *No.* 1.

I must add, however, that whilst in most, if not all other, large building establishments, means are adopted for the seasoning of their timber, by procuring it long before it is required for use; in the Engineer Department we are necessarily obliged to wait for the annual vote of Parliament, before we can demand our materials; which reduces us to the only alternative, of having recourse to open contracts, for the suply of such materials as we may from time to time require, or, in other words, to "work from hand to mouth."

Without calling in question the due fulfilment of these contracts, at many stations, in supplying well-seasoned timber whenever required, I may state, I think without fear of contradiction, that at some the demand is too trifling or uncertain to offer any inducement to men, the extent of whose business enables them to have well-seasoned timber always on hand, to enter into contracts with the department.

Whilst at more important stations, in order to become a Government contractor, the competition is frequently so great, as to cause tenders to be made at a very low rate, and constant complaints, at the inferiority of the articles supplied, the result of their acceptance.

In the colonies (within the tropics at least), in addition to these difficulties, which are all increased from their isolated position, nature has provided other enemies to the durability of timber.

I allude to the termite,* or white ant, who, like all his family, displays little short of reason in the ingenuity of his destructive attacks. Like the experienced miner, he proceeds with unerring certainty in the destruction of whatever building, magazine, or other strong-hold of supplies he invests, without ever exposing himself to the fire of the enemy by coming to the surface: like the rat in the ship, who is said to be well aware that were he to eat through the bottom of the vessel, it would be to his own destruction. Against so insidious a foe, then, nothing but rendering the material unpalatable can accomplish a victory. From the testimony of Mr. Kyd, of Calcutta (quoted in the Company's prospectus),

* Smeathman, in the Philosophical Transactions for 1781, and Kirby and Spence, in their Introduction to Entomology, vol. ii. page 26, give very curious and interesting descriptions of the habits and sagacity of this insect.

it would appear, that the trials of the solution for this object, have, as far as they have gone, been satisfactory.*

Lieutenant-Colonel Reid, Royal Engineers, also informs me, there is one of the beetle tribe that deposits its eggs in the bamboo at a particular season of the year, or, as the negro avers, at a particular quarter of the moon, and that when these eggs are hatched, the young insects live on and destroy the bamboo.

I think it very probable the solution would prevent this deposit ever coming to life, or if it came to life, deriving its support at the expense of the bamboo.

If so, a very light and useful wood of rapid growth would be preserved and rendered available for many valuable purposes.

In rafters, for instance, to the smaller description of houses, which, with a thatch of palmetto leaves, makes, as I can testify by several years experience, the coolest and most agreeable roof for a tropical climate, being more secure in blowing weather than either the shingle † or slate; the palmetto leaf permitting the wind to pass through it, thereby offering less resistance to its fury.

* I may here add, that I have seen in the West Indies a field-piece brought out of store to be used in firing a salute, when the carriage, though apparently sound when in store, was, on being put in motion, found unserviceable from the concealed attacks of this insect.

Also I remember, on taking a remain of stores, to have seen whole boxes of shot with wooden bottoms, so completely destroyed, as to leave little more than the shot with the pieces of tin by which the wooden bottoms were attached to them, remaining. These on the survey were marked "repairable," and usually sent home (by order) to be repaired, to be again sent out to meet a similar fate; thus making the departments at home mere commissariat store-houses for the supply of food for this little miner of the tropics.

† I will here remark, that I conceive great increased durability will be given to every description of shingle by the application of this process; and as this kind of roof cannot be *effectually repaired*, and at present only lasts from twenty to thirty years, this would be a valuable discovery in the West Indies, where it is in such general use, and where labour forms so considerable an item of expense in building. The durability of laths also would be much increased by being saturated.

*Table showing the Effects of the Process of Saturation on the Strength of Timber.*

| Nature of the Wood. | Weight of the Specimen. | Specific Gravity. | Distance between bearing. | Length. | Width. | Depth. | Deflection. | Weight at which Wood deflected. | Broke at. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. oz. | | ft. in. | ft. | in. | in. | | | | |
| Ash .... not saturated | 4 1½ | 786 | 2 10 | 3 | 2 | 2 | ¼ of an inch. | 775 | 2231 | It would appear from these trials, that the specific gravity of the wood is slightly diminished by saturation; that it is rendered stiffer, but more brittle. |
| Ash .... saturated ... | 4 1 | 780 | ,, ,, | ,, | ,, | ,, | | 999 | 2175 | |
| Christiana deal... not saturated | 2 4¾ | 441 | ,, ,, | ,, | ,, | ,, | | 663 | 1279 | |
| Christiana deal... saturated ... | 2 2¾ | 417 | ,, ,, | ,, | ,, | ,, | | 719 | 1167 | |

I look forward also to the substitution of timber, in some cases, for masonry; —in the coping of walls from one to four feet in thickness, which in military works may include superior slopes to their stone parapets; loop-holed, and retaining walls, and boundary walls, to barracks and magazines. Also in park, garden, and church-yard fences.

It has always appeared to me that the decay of these walls, and the consequent continued pointing required, has arisen chiefly, if not entirely, from the number of joints in the coping, whether of brick or stone. A crack in the joints of these copings is seldom seen or attended to, till its effects are visible in the wall itself; exterior pointing is then had recourse to and the evil checked, but

The above are the only trials hitherto made; but as similar results are obtained in both cases, though with different kinds of wood, it is thought their introduction here may be of some use.

The penetration of the solution into the wood may be tested by the application of a drop of the hydro-sulphuret of ammonia, which will turn black on meeting with the mercury.

Professor Faraday says, with respect to penetration, "In the cube of elm, the corrosive sublimate may be traced by the above test, to the depth of from one-fifth to one-fourth of an inch; by the test of voltaic action, from three-quarters to one inch.

"In the cube of oak, with the same test, it was found at one quarter of an inch, but it was irregular, and apparently followed the fissures of the wood. By voltaic action not quite so far as the elm.—Cube of fir. The penetration here was in the smallest degree: by the common test, one-eighth or one-sixth of an inch, and by the voltaic battery half an inch. The turpentine in the wood had probably been the obstruction to penetration." Professor Faraday also states—

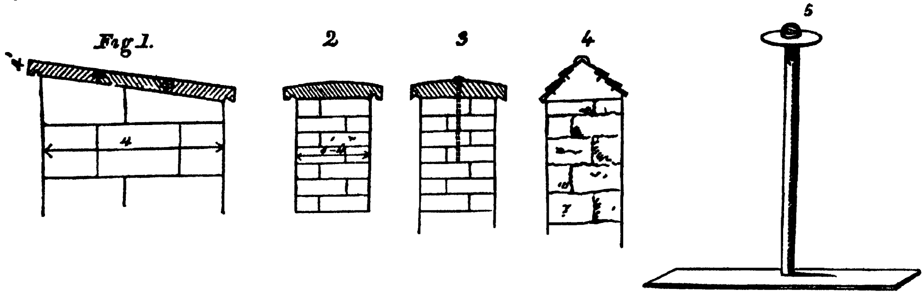
In considering this process, he has always looked upon the excess of preservative, i. e. corrosive sublimate, in the parts towards the exterior of the timber, as a most important condition, for he finds that at least three-fourths of that can be removed by water, provided the wood be thoroughly disintegrated; and a strong argument with him in favour of the process, is the well-known fact, that such matter will not remain where it is at present, but will gradually penetrate the wood, by those forces which tend to give a uniform distribution of fluid within the pores of any porous matter, and which will be influential, though the pores be not full of fluid, the wood being in what is usually called a damp state. There is one other consideration which is of importance to him, in forming a judgment on this process; it is, that where the exterior is preserved from change, the chances that the interior will decay are greatly diminished. A strong and well-known fact on which he reposes this opinion is, that of the preservation of piles or timbers, charred on the outside; and as in those cases the interior parts are preserved from decay for a much longer period, so he thinks it safe to conclude, that even an external preparation only of a timber would greatly diminish the probability of internal decay; and this, in combination with the gradual penetration of the substance to the centre, is the reason why he entertains little doubt of the value of the process.

These reasons, combined with a close examination of specimens shown him, make him strongly recommend it; and he would be quite willing, if there were occasion, to trust a good deal of property upon it.—Vide Minutes of Evidence in Report of Committee appointed to investigate Mr. Kyan's Patent for the Prevention of Dry-rot, published by order of the House of Commons, 9th July, 1835.

not removed from the interior of the wall, where it remains ready to be increased by the next crack in the coping.

In Canada, where pointing, even in cement, cannot be done with advantage more than three months in the year; in this country, where wet and frost succeed each other during many months in the year; and in the tropics, where the rapidity of vegetation is visible in the joints of masonry, and destroys them in a very short time, the substitution of wooden coping would not only be very economical in the first instance, but render the wall infinitely more durable.

The following may be given as varieties of wooden coping:—




These copings may be secured by wooden bricks, built into the wall at intervals, or by iron three-quarter-inch pins, with nuts and screws at the top, and welded at the other end to a piece of No. 10 gauge-iron, two inches by one foot six inches, built into the wall; the pin passing through the coping is secured by the nut, a piece of sheet-lead being put between the coping and the nut, to keep the wet out. *Vide figs.* 3 and 5.*

* I should have substituted wooden coping in the parapet-wall of the Greenwich railway, instead of the present one, which is brick, covered with cement, and which, either from the greenness of the masonry, or the tremulous motion caused by the traffic of the carriages, or perhaps both, has cracked and peeled off, and given the wall the appearance of being in a state of decay rather than of a new work. I consider this description of coping particularly adapted for viaducts and other bridges on railways, as there is no access to it, to enable boys and other mischievous and idle persons to disfigure it by cutting their names in it.

The introduction of wooden sleepers, of green larch and other cheap indigenous woods, Kyanized, is becoming very general on railroads, in new-made embankments, where settlement may be expected; and I should be glad to see it generally adopted, as, in the present infant state of this new mode of communication, many alterations must or ought to be calculated upon; particularly in the width of the rails, which I expect will ere long be much increased, and which, in those laid on stone blocks, must be attended with great expense: indeed, I prefer the chairs being permanently laid on longitudinal pieces of timber on concrete foundations, to the present mode, by which so many chairs are cracked by the jar in fixing to the blocks, which would not occur in the timber, the chairs being screwed down.

In

No. 4 is the method used in Canada in common rubble walls, and first suggested to me the idea of the general substitution of wood for stone or brick in common coping. The first three of these copings are easily given the appearance of stone, if required, by dashing sand or sifted quarry-stuff against the painted or tarred surface when wet.

In Nos. 2 and 3, there may be said to be no joint at all, for good scarfing, put together with white lead, is as tight as the wood itself.

I had written thus far, when I was informed of the return of the ship Samuel Enderby, alluded to in a former note, as having been built entirely of saturated timber; the same process having been also applied to the sails and rigging.

It was said she had returned in a state of decay, and that the experiment was a complete failure.

I lost no time in going on board and inspecting her, as well as in making inquiries as to the health of the crew. The mate informed me they had all been quite healthy, that no death had occurred during the twenty-nine months they had been absent, and that since May last they had not had even a medical man on board. I next examined the bilge-water; it was without any unpleasant taste or smell, excepting what arose from the oil that floated on the surface, the ship having a full cargo of sperm-oil. On examining various parts of the timbers of the vessel, from the upper deck to the keelson, they were perfectly sound. The mate said he considered the vessel as sound as the day she was launched, and a very tight ship.

With respect to the sails and rigging, however, he said they had not answered as well as was expected; and on inquiring at Mr. Enderby's manufactory, where they were made, I found that it was not the first time this had occurred, where the canvass* had been constantly exposed to the light, though it had invariably

In advocating the substitution of wood for stone in copings, I am far from wishing to under-rate the mode of building so generally adopted at present, of giving all houses and other edifices the appearance of stone, and of adding architectural embellishments, by means of cement.

I have confined myself to such works as are more simple in their construction, and the keeping of which in repair, or otherwise, does not tend directly to the comfort or discomfort of man, and are less liable therefore to be constantly watched.

* Professor Faraday, on examining this canvass, stated that he found the *warp* sound, whilst the weft was decayed; from this it may be inferred, that the fault lay in the material and not in the preparation.

An iron bolt, taken out of the Samuel Enderby on her return, was apparently a good deal corroded, but being tested by Professor Faraday, exhibited no trace of mercury.

succeeded under the most unfavourable circumstances and situations, where light was excluded or only partially admitted.

It becomes therefore a very interesting question, whether light does not cause some chemical action to go on prejudicial to the fibres of the prepared canvass, and particularly in such as has been previously subjected to the process of bleaching with chloride of lime and sulphuric acid.

The rigging was entirely composed of white rope. From the short time this vessel has been built, it cannot be considered as a sufficient trial; but it adds another to the many instances of the successful application of this process to *timber*, without my having been able to meet with a single instance of failure.

From the foregoing remarks, I earnestly hope I shall induce Commanding Engineers to give this very ingenious and long-sought-for discovery, a full, fair, and impartial trial: its success (of which I confess I am sanguine) will be a source of great economy to the department; and have the inestimable advantage to the Corps, of materially reducing the least agreeable part of their duty—the repair of barracks and other public buildings, by rendering their first construction more durable; and thus leave to its officers more time for the prosecution of the higher branches of their profession, to the study of which, I trust, an additional stimulus has been given, by the commencement of the present channel of communication.

R. C. ALDERSON,
Captain, Royal Engineers.

(Copy.) APPENDIX, No. 1.

*From the Commanding Engineer to the Inspector-General of Fortifications, requesting Authority for the Use of a Tank for Kyan's Patent for preventing Dry-Rot.*

SIR, Woolwich, 21st September, 1836.

In the numerous buildings at this station, some situated on the marshy soil of the arsenal, and others on the damp clay of the upper part of the common, I find the wood-work in floors, joists, skirting-boards, door-posts, &c. decay so fast wherever the dry-rot once attacks a building, that I am induced to request permission to be allowed to use Kyan's process for preparing timber; and that, as the expense of sending the wood to the Company's station at the Surrey Canal Dock, to have it saturated there, is considerable, the Anti-Dry-Rot Company may be permitted to furnish a tank for the engineer work-yard, agreeably to their offer in the accompanying letter.

On looking over the estimates for the last five or six years, I perceive that at least 300*l*. or 400*l*. has been expended yearly in repairs, rendered necessary by dry-rot and decay in timber, besides the casual repairs, which being done under the incidental item, cannot well be ascertained.

I had occasion, on the 28th of July last, to write to you on the subject of thus preparing the floors now lying at the repository, and then mentioned, that in the lining which was put up at the Lieutenant-Governor of the Academy's house in 1834, as an experiment, the prepared part was perfectly sound, whilst that unprepared was much decayed; and as the reports of many practical and scientific men are highly in favour of this process, and it is every day coming into more extensive use among builders, I am induced to recommend the use of it in the Engineer Department here, where we have so much timber in damp and exposed situations; for, as the expense will be trifling, and may in most instances be covered by the contingencies of the estimates, there appears to be good reason to think, that a great saving may accrue from it in the general expenditure.

The terms proposed by the Company, are the same as those generally charged; and I have arranged with the Directors that the account of timber so prepared shall be kept in this office, and their bills made out from it, the quantity of solution supplied being, they consider, a sufficient check for them.

As the tank they supply will be large, the other departments at Woolwich may thus have any timber, canvass, cordage, bags, &c. prepared, which they may desire, by sending to our yard, without further reference to the Company, or forwarding the articles to their stations.

I have the honour to be, Sir,

Your most obedient humble Servant,

(Signed) GEO. G. HARDING,

Lieutenant-Colonel, Commanding Engineers.

To Major-General Sir FREDERIC MULCASTER,

Inspector-General of Fortifications, &c. &c. &c.

(Copy) APPENDIX, No. 2.

Anti-Dry-Rot Company's Office,
2, Lime-Street-Square, Sept. 19, 1836.

SIR,

I am instructed by the Directors of this Company to acquaint you, for the information of the Board of Ordnance, that, to save trouble and expense of removal to the Company's station, the Directors are willing to lay down a tank in the arsenal, and to prepare, at their own cost, all the timber and wood that may be required, at the same price hitherto charged to the Ordnance at the Company's stations, viz. 20*s.* per load of fifty cubic feet, and 5*s.* per cwt. of canvass, cordage, bags, &c., the whole to be under the superintendence of any person the Commanding Engineer may think fit to approve.

I have the honour to be, Sir,
Your very obedient Servant,
(Signed) CHARLES TERRY,
Secretary.

To Colonel HARDING,
Commanding Royal Engineers, Woolwich.

(Copy) APPENDIX, No. 3.

Royal Carriage Department,
25th March, 1835.

SIR,

According to your directions, I proceeded on the 9th instant, with the Deputy Storekeeper and Constructor of this department, and Mr. Terry, on the part of Mr. Kyan's patent, to examine the undermentioned articles, which have been eighteen months under trial; and I have to report as follows, viz.:

Placed in contact with, and under the flooring of the old Cadet-hall, which is much affected with dry-rot—

Prepared with Kyan's Patent,

| | Inches. | |
|---|---|---|
| 1 piece of oak of 24 inches | 3 × 3 | 1 piece of white rope .... 5-inch |
| 1 do. ash 24 do. | 3 × 3 | 1 do. do. .... 2½-inch |
| 1 do. elm 24 do. | 3 × 3 | 1 do. do. .... 1¼-inch |
| 3 do. Memel fir 23 do. | 4 × 2 | 1 do. tent-line, or cordage, |
| 3 do. American fir 23 do. | 4 × 2 | 4 do. canvass, |

with duplicates of *exactly similar materials* "unprepared."

We found all the rope, cord, and canvass, that were unsaturated with the patent, had become more or less rotten, except one piece of canvass; but no material alteration in the wood, except in one piece of Memel, and one of American "*unprepared*," which, with their fellow pieces "*prepared*," Mr. Terry wished should be taken up, considering those two woods to be touched with "dry-rot," the other fourteen pieces were left under the floor.

We then had the following pulled up out of the ground, into which they had been driven fifteen inches, and the tops exposed to a southern sun, and to the drip, &c. under the eaves of a building, viz.:

*Prepared* with Kyan's Patent.

| | Inches. | | Inches. |
|---|---|---|---|
| 1 piece of oak of 24 inches | 3 × 3 | 1 piece of Memel fir of 23 in. | 4 × 2 |
| 1 do. ash 24 do. | 3 × 3 | 1 do. American fir 23 do. | 4 × 2 |
| 1 do. elm 24 do. | 3 × 3 | | |

and exactly similar pieces of the same woods "*unprepared.*"

This trial appeared to have had rather more effect on the wood than the preceding one at the Cadet-hall; and as Mr. Terry wished all the pieces of wood which had been removed to be left to dry for a week, his request was complied with; and at the end of ten days we saw them again, and only found, materially damaged, the one piece of elm, which was "*unprepared*," whilst the one "*prepared*" was perfectly sound.

The whole of the pieces of wood, canvass, cord, and rope that were removed, have been put back into their former situations, for further contact to dry-rot, and exposure, &c., agreeably to your recommendation to the Board, that a second examination may be made eighteen months hence.

The wood used in the foregoing trials was on an average of about two years' seasoning.

I have the honour to be,

Sir, &c. &c.

(Signed) RICHARD HARDINGE,

Assistant Inspector,

President.

To Colonel Sir JOHN MAY, K.C.B.

Royal Carriage Department, &c. &c.

(Copy)

## APPENDIX, No. 4.

Royal Carriage Office,
Woolwich, 28th Sept. 1836.

SIR,

In furtherance of your directions, that a second examination should be made at the end of *three years*, to try the effect of Kyan's patent, I have again to report (and referring to my former one to you of the 25th March, 1835), that this day, accompanied by the same persons as on the first occasion, namely, the Deputy Storekeeper and Constructor of this Department, and with Mr. Terry on the part of Mr. Kyan, we examined the different pieces of wood, canvass, and rope submitted for experiment.

1st. We agreed in considering, that on the "prepared" woods, canvass, rope, and cord laid down in contact with dry-rot under the floor of the Cadet-hall, no impression has been made; and on the duplicate pieces "unprepared," very little effect has taken place on the woods; but the canvass, and more particularly the rope and cord, are very much decayed.

2nd. Of the pieces of wood partly driven into the ground under the eaves of a building, and exposed to the united action of sun, rain, and damp earth, we also agreed, that all the five pieces of oak, ash, elm, Memel fir, and American fir, "prepared" with the patent, are quite sound; whilst of the duplicate pieces "unprepared," the elm and ash were rotten, and the progress of decay had commenced in the three others, the oak being least affected.

The woods used in the foregoing trials had, previously to being put down, been seasoned two years.

We then proceeded to examine what you, at Mr. Terry's request, had placed under the same test as the last described woods, it appearing to be the most severe trial, viz.:

A piece of oak, five feet long, three inches diameter.

A piece of ash, two feet five inches and a half long, six inches and three quarters diameter.

A piece of elm, five feet one inch long, three inches and one-eighth diameter.

All of which came here quite in a green state, and with the bark and some leaves on them, and after being split down the middle and marked, half of each specimen of wood was returned to be saturated with the patent, and when sent back again the whole were put down, 31st March, 1835.

They were taken up a few days ago to dry, and we find at the end of the year and a half, that the "*prepared*" pieces, even to the preservation of the *bark and sap*, are perfectly sound, and the "unprepared" quite *rotten*.

I have the honour to be,

Sir, &c. &c.

(Signed) RICHARD HARDINGE,

Assistant Inspector.

To Colonel Sir JOHN MAY, K.C.B.
Inspector, Royal Carriage Department.

P. S.—After Mr. Terry was gone, the quality of the prepared two-inch rope was tried, with heavy weights, against a piece of new rope of the same description, when the strength of the former did not appear to have been at all affected by the three years it had remained under the floor of the Cadet-hall.

R. H.

## XX.—*Hints for the Compilation of an Aide-Mémoire for the Corps of Royal Engineers.*

THE advantage to the Engineer Service of a Memorandum-Book, containing in a condensed form details relating to our military duties, has been always admitted, and the want of one has been at all times regretted. The reasons why such a work has not long ago been formed, are the time and labour required to form even an imperfect first edition; and the impossibility (owing to the extensive range taken in the military part of our duties) of one officer alone, or even a very few, combined for the same purpose, succeeding in an attempt to make a publication worthy of the service. But if the Corps Officers generally can be induced to contribute what professional notes they possess, there is ample reason to expect that a work of the nature required might be very creditably completed.

It is hoped that, through the medium of this volume of Professional Notes and Memoranda, supported by the Head of the Corps and the Master-General of the Ordnance, the great disadvantages arising from the dispersion of the Officers may be at last overcome.

The department has been essentially benefitted for service in the field by the Chatham School of Military Instruction, and by the formation of a good corps of Sappers and Miners; but the equipment of materiel for the field has been scarcely at all advanced: and after all the experience of the war, we have little besides the valuable notes at the end of 'Jones's Journal of Sieges;' and but very little has been decided, upon the subject of field equipment, since the time when those notes were published. Were circumstances to require a British army in the field, the Engineer Department would be scarcely better prepared than on former occasions; except in having the aid of the corps of Sappers and Miners. In the course of forming a field Memorandum-Book, all that is required for field-equipment in materiel would be gradually developed: and when the best equipment may be decided upon, it is essential to have a proportion systematically packed, in its field-carriages, or for the pack-saddle: and in order to arrive at and maintain a system fit for war, it is necessary frequently to horse the field-carriages, and move them as on a march.

To ensure the progress of the undertaking, and to render the materials preparing for it useful from the outset, it will be desirable to print in this volume, all (or the greater part of) original information applicable to the Aide-Mémoire. This course is certainly one which involves expense, and the progress will be slow, but it does not preclude the adoption of other means that may be devised for its advancement; and in the mean time, it will permanently secure for the public service whatever may be contributed.

From time to time, headings of articles, which it is desirable should be filled up, will be printed, with a view of inviting Officers to send information under these particular heads; and when, by these and other means, sufficient articles may be procured, to merit being collected into a separate volume, it is proposed to arrange them in order for publication.

It would obviously be unnecessary to reprint materials from works of easy access: but references to articles in such works should be printed for the reason above stated, viz. that they may be secured for the benefit of the service. It is also proposed to print forms of tables, and to invite the Engineer Officers to assist in filling them up; and to reprint them, from time to time, until they are sufficiently amended.

It must occur, that there will be articles which cannot be very much condensed, but which can be given in the shape of records of what has been done. The following explanation of the way in which some bridges were blown up in the Peninsular war, will serve as an instance; but, as the first volume of the Notes and Memoranda is in the press and nearly printed off, examples cannot now be multiplied.

W. REID,

Lieutenant-Colonel, Royal Engineers.

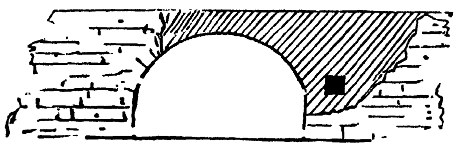


On

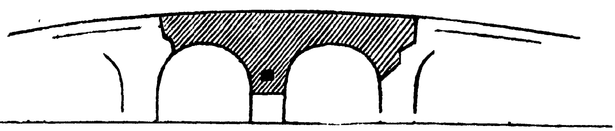
*On the Destruction of Stone Bridges.*

The usual method of destroying stone bridges in the Peninsular war, was to sink a shaft close to the parapet-wall, and to carry it down to the level of the springing of the arch to be destroyed. When at that level, a horizontal gallery, or excavation, was made, so that the charge of gunpowder might be placed under the middle of the roadway. The shaft was made as small as possible, in order that the resistance offered to the explosion might be the nearer balanced on the two sides of the bridge; and, when there was time, the shafts were always tamped with the greatest care, strong crossed timbers being generally inserted with the tamping. When the mine was to remain loaded for some time, the powder and its train were placed in well-pitched boxes.

The following figures show the breaches usually made. The first represents the breach of a single arch, after a mine has been sprung;



and the second shows the usual shape of the breach when it is intended to destroy two arches.



In the second, the powder must be placed with the greatest exactness in the centre of the pier, between the two arches intended to be destroyed; for if it be placed sufficiently off from the centre, it will destroy one and leave the other standing; and this was frequently done on purpose in the Peninsular war.

One barrel of powder which contains ninety pounds will destroy most bridges, if there be time to place this charge in the most advantageous manner.

But it will often occur, that bridges are to be destroyed when there is too little time to complete the usual mine; as, for instance, when an army is retreating before a superior enemy. This was the case at the bridge of Tordesillas on the Douro, during the Burgos retreat in 1812; for when a detachment was sent to destroy this bridge, a large French force was marching to the same point for the purpose of seizing it, and turning, by passing it, the left flank of the Duke of Wellington's army.

The Engineer Officer employed, knowing how difficult it was to sink behind the arches of some of the old bridges in Spain, began two mines at the same time; one at the usual place, by the side of the parapet, and the other on the crown of the arch in the middle of the roadway. The first was soon found to be impracticable, from its hardness and solidity. The second was therefore used, and succeeded. The paving-stones of the road were taken up, and a hole sunk so as to give the ignited gunpowder some part to act upon laterally; but care was taken not to make the hole so deep as that the line of least resistance downwards should be so short as to produce only a round hole. Heavy stones from the parapet were piled over the gunpowder. The charge was three barrels: it destroyed one complete arch.

The same Officer had previously blown down another bridge with one barrel of powder; but in this instance there was time to cut away part of the key-stones on both sides of the bridge.

When a bridge was to be destroyed, as soon as the mine was completed, the gunpowder was placed in biscuit-bags procured from the commissariat. One barrel of ninety pounds was found sufficient to destroy two arches, in each of two fine bridges upon the river Yecla, between Salamanca and Ciudad Rodrigo, in 1811. But the mines which were made for these charges cost a fortnight's hard work, the parties working by reliefs night and day. The arches were backed with a concretion of silicious pebbles, and the progress of the miners for a great part of the time did not exceed one inch an hour.

It would probably not require a very great quantity of powder to blow downwards any arch, even if the powder were merely placed on the top of it and fired. Perhaps very few arches would resist the shock of 1000 lbs., or eleven barrels, exploded upon them; and cases might frequently occur in war, when this mode might be the only one open for trial. If 1000 lbs. of gunpowder were placed on the crown of an arch, the carriage which transported it being afterwards turned over upon the top of it, and then a mass of stones placed on the carriage, there would be little doubt but that most arches would fall down from the shock.

Every army should be attended with equipment complete within itself for destroying bridges. The patterns of such equipments should exist in our arsenals: they should be arranged in different proportions: and at the place of drill and field-training, such equipments should sometimes be seen horsed.

W. REID,
Lieutenant-Colonel, Royal Engineers.

# PROFESSIONAL WORKS LATELY PUBLISHED.

"Ideas as to the Effect of Heavy Ordnance, directed against, and applied by Ships of War: particularly with reference to Hollow Shot and Loaded Shells." By T. F. Simmons, R. A. Published by Egerton, Whitehall. 135 pages, 8vo. 7*s.* 6*d.*

Although this work applies chiefly to the navy, it is nevertheless of interest to those who have to construct defences against attacks which may be made from the sea. A considerable portion is on the subject of the penetration of shot, and of the effects of solid shot when compared with hollow shot and loaded shells. The effect of loaded shells of large diameter, fired horizontally at ships, are such as make it desirable that sea-batteries should be armed with guns suited for firing them, like General Millar's new ten or twelve-inch guns. Captain Simmons has made better known, also, a small pamphlet by the late Captain Hastings, R. N. who commanded a Greek steam-ship, from which he fired 18,000 shells without accident.

Captain Simmons also considers several other subjects of interest, such as the windage; reaming-up or boring-up a small gun to carry a larger shot, which both the French and ourselves are doing; the French experiments with loaded shells against ships, &c.

"Expériences Faites à Metz en 1834, par Ordre du Ministre de la Guerre, sur les Battéries de Brêche, sur la Penetration des Projectiles dans divers milieux resistans, et sur la Rupture des Corps par le choc." Paris. 1836.

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