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PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS.

CONTRIBUTED BY OFFICERS OF THE ROYAL ENGINEERS

AND

EAST INDIA ENGINEERS.

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PREFACE.

The subscribers to this volume will observe with regret that it contains no accounts of the Engineering Operations at Delhi and Lucknow, but I hope that these will be obtained in time to appear in the next, for they will be of great value in showing that when troops have science, discipline, and determination on their side, they can, with the Divine blessing, overcome an enemy greatly superior to them in number.

The account of the Experiments on Embrasures carried on in the United States will prove useful in determining the best construction for those in casemates, to render them capable of resisting the effects of artillery of greatly increased power which are likely to be brought against them, keeping in view the fact that our own later experiments have proved that by the application of improved trucks to traversing platforms, pivots will no longer be required.

The Papers on the Engineer Equipment of the Turkish Contingent and on the Influence of the Modern Rifle direct attention to a most important subject, for it is often very advantageous to be able to construct extensive entrenchments during a single night, so that, in case of an attack, the assailants may find themselves *unexpectedly* checked by them; and this can only be done by organizing a sufficient Engineer Equipment *capable of being rapidly moved* through the most difficult country, since it is evidently useless to increase the number of skilled workmen in an army if ample means are not afforded for supplying them with tools under all circumstances.

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

NOTICE.—The three numbers of the "CORPS PAPERS," published in 1848, '49, and '50, can now be obtained, bound in one volume, uniformly with the "Professional Papers," for £1, on application to Mr. Howlett, at the office of the Inspector General of Fortifications, Whitehall.

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BY BREVET BRIGADIER-GENERAL JOSEPH G. TOTTEN,

COLONEL AND CHIEF ENGINEER, UNITED STATES' ARMY.

CHAPTER I.

INSTRUCTIONS AS TO BUILDING THE TARGETS—DESCRIPTION OF SAME—AND TABLES OF FIRINGS FROM AND AGAINST THEM.

SECTION I.

GENERAL DESCRIPTION OF THE TWO EMBRASURE-TARGETS.

1. It is necessary to state, in the first place, that there were two embrasure-targets built, and experimented upon in succession.

2. The *first*, erected in the summer of 1852, and destroyed by firing against it in the autumn of 1853, consisted of a wall about sixty-seven feet long, ten feet high, and five feet thick, containing six embrasures, which are designated in the following pages as Nos. 1, 2, 3, 4, 5, and 6; they are shown on Plate I., Figs. 1 and 2.

3. And a *second*, of about the same dimensions, erected in 1854, and destroyed in 1855. This target, containing three embrasures, namely, Nos. 7, 8, and 9, is exhibited on Plate II, Figs. 3 and 4.

4. As it may conduce to a clearer understanding of the objects in view, the process followed, and the results obtained, the descriptions of the targets, and the tabulated results as to each, will be kept separate, the latter being given in the order of proceedings.

5. And to assist in the explanation, some extracts will be made from the directions issued from the Engineer Department for their construction.

SECTION II.

Instructions for Building First Target—Description of Mortar and different Concretes used.

6. In the instructions of July 14, 1852, addressed to Captain Henry Brewerton, then Superintendent of the Military Academy, West Point (New York), it is said by the Chief Engineer:—

"I have long deemed it of great importance that some decisive experiments should be made to ascertain, of the materials generally applicable to the construction of embrasures for casemate guns, which is the better in reference to the effect thereon of an enemy's fire; and I have now obtained the consent of the Hon. Secretary of War that some experiments of that nature should be made.

7. "A range of 200 yards will suffice, and is, perhaps, the best for the objects in view. These objects are principally two, namely, to ascertain—

"1st. The effects of solid shot from guns of large calibre upon different kinds of masonry around the embrasure, and especially upon the material constituting its outer edges and the flaring surfaces, and also the effects upon the throat of the embrasure.

"2nd. The effect of grape and canister shot upon the outer surfaces and throat, and the number of balls that pass, either directly or by reflection, through the embrasure into the casemate.

"And it may be advisable to profit by the opportunity in making, 3dly, some trials of the effects upon the same materials, of shells fired horizontally.

8. "In order to the execution of these objects, there has been prepared in this office, and approved by the Secretary of War, a drawing of a masonry target 67′ 8″ long, 5 feet thick, and 10 feet high above the foundations, containing six gun-embrasures of dimensions adapted to casemated batteries.

9. "*Embrasure No.* 1, being that on the right, looking at the target, will be made of large blocks of granite, rough hammered on the faces, but with well cut beds.

10. "*Embrasure No.* 2 will be made of cement-concrete, and will be surrounded by granite masonry. Both these embrasures (and also No. 6) are of the general form and dimensions of those last constructed in the fortifications; and like those formerly constructed, excepting that the exposure is made somewhat less, by rounding the junctions of the cheeks with the sill and lintel.

11. "*Embrasure No.* 3 is made of cement-concrete,* and is surrounded partly by the same kind of concrete, and partly by rubble-stone masonry. The throat of this embrasure is materially lessened, and is formed by a mass of wrought iron, eight inches thick, composed of sixteen plates, each half an inch thick; and the outer concrete cheeks are notched, so as not to present oblique surfaces to an enemy's missiles.

12. "*Embrasure No.* 4 is made of asphaltic-concrete, and is surrounded by rubble-stone masonry. One half the throat and one cheek are like No. 3. The other cheek, including the throat, is provided with three wrought iron plates, each 6″ by 2″, the cheeks being notched, to expose parts of the surface of these plates, in planes parallel to the face of the wall.

13. "*Embrasure No.* 5 is composed of blocks of lead-concrete on one side, and of cement-concrete on the other—all being embedded in a brick wall, or rather a wall of rubble masonry, faced with bricks; both the outer cheeks of this embrasure will be notched and supplied with plates of wrought iron 6″ by 2″, like those last described in embrasure No. 4.

* See paragraph 18.

14. "*Embrasure No.* 6 will be made of brick-work, and surrounded by brick-work backed with rubble masonry.

15. "To lessen expense, the details of tongue holes, pintle holes, and other matters necessary to the service of guns in embrasures, but not contributing to the strength of the wall, will be omitted, except in embrasure No. 3, and this must be fitted to receive a gun, in order to try the effect of the blast upon the throat-irons—this being the first experiment to be made. Of course the ground behind this embrasure must be levelled, and some planks pinned down to the earth to serve as traverse circles. It will be necessary also, probably, to throw up a small mound of earth to receive the balls fired from the embrasure.

16. "With the same object of lessening expense, the back face of the wall will be laid up of the cheapest material. This may be rubble masonry, but if a facing laid with common bricks will be less expensive, such should be adopted. * * * * Behind the target, and at the distance of about three feet, there should be erected a rough board fence to show the marks of all balls or fragments that pass through the embrasures. * * * *

17. "The engineer company should construct the platform for the gun that is to be used against the target. If you have a 32-pdr. or a 42-pdr., either will answer. The same company should lay the plank traverse circles for the casemate gun of embrasure No. 3; any gun that you may have mounted on a casemate carriage will do for this service. I mean of course, 24, 32, or 42-pdr., or 8-inch columbiad. * * * *

18. "On further consideration it is deemed better to make one of the outer cheeks of embrasure No. 3 of bricks; leaving the other cheek as before stated, of cement-concrete, the sole and lintel being of cement-concrete."

19. In building the targets, the mortar used in laying the stones and bricks, and in compounding the cement-concrete, was composed of one measure of cement* in dry powder, and one of clean sharp sand.

20. The "cement-concrete" was made by mixing with rather small fragments (say from half a cubic inch to six cubic inches each) of bricks or stones, clear of all dirt, a quantity of the mortar just described, somewhat greater than the measure of the void space in the bulk of fragments.

21. The "asphaltic-concrete" was composed of like fragments of bricks or stones, into which was poured, while hot, a quantity of asphaltic mastic rather exceeding the measure of the void spaces—the proportions in the mastic of pure asphalte to the "calcaire," being such that the mastic would retain its form in the face of the summer's sun at West Point.

22. The "lead-concrete" was formed of like fragments and in like proportions. The fragments were well heated before being poured into the mould, and the melted lead was added immediately.

23. There was no practical difficulty in making these blocks of lead-concrete, and asphalte-concrete, in place; giving to them accurate forms and dimensions, with surfaces even, and free from hollows.

23 *bis*. In Figs. *a* and *b*, Plate III., are exhibited the details of wrought iron shutters that were mounted by hinges upon the iron throat-plates of embrasure No. 3.

* The term "cement" is applied in these notes, as generally in this country, to a material possessing considerable hydraulic energy. The test applied to inspections under the Engineer Department, requires generally that a cake made of pure cement, immersed in water before hardening, shall in a few minutes, support a wire one-twentieth of an inch in diameter, loaded with the weight of one pound.

SECTION III.

Tables, from 1 to 7 inclusive, of Firings from and against the Embrasures of 1st Target; and Remarks upon Table No. 1.

Table No. 1.

Firing from 1st Target, through Embrasure No. 3. to test the effect of the Blast of the Gun upon the Embrasure.

Gun, 42 pdr.: Length, 10′ 9″: Weight, 8,465 lbs. Casemate Carriage.

Order of firing.	Calibre.	Charges of powder.	Projectile.	Elevation.	Direction.	REMARKS.—November 11, 1853.
No.	lbs.	lbs.		degrees		
1	42	10	Ball	0	Direct	No effect, except partially closing the shutters. They were found ajar, after the discharge.
2	42	10	Ball	0	8° Oblique	No effect, except partially closing the shutters. The joints between the iron plates and the brick and cement on either side unaltered.
3	42	10	Ball	0	15° Oblique	No effect, except partially closing the shutters. The joints between the iron plates and the brick and cement on either side unaltered.
4	42	10	Ball	0	22° Oblique	The shutters remained open, perhaps because the mound erected in front to receive the shot, being considerably blown away by the previous discharges, the blast was diminished. The joints around, and exterior to, the throat, showed no tendency to open, nor any movement whatever.
5	42	10	Ball	0	30° Oblique	No effect upon the embrasure. One shutter closed after the discharge; the marks left upon the salients of the offsets nearest the shutters, indicated that the tendency of the blast to press them further open must have been very severe.
6	42	10	0	5	Direct	Thick wad of turf instead of ball. No effect upon the embrasure. The Gunner nearest the piece thought the shutters closed at the discharge and then rebounded. They remained partly open. The marks upon the corners of the nearest offset considerably enlarged, resembling the effects of a blow from a hammer. The straps of the hinges are the only portions of the shutters which can be put in contact with the offsets.
7	42	10	0	5	Direct	Thick wad of turf instead of ball. No effect upon the embrasure. Some moist clay, of the consistence of dough, was placed (before the discharge) against the exterior of the gorge plate to show whether the shutters actually closed or not. From this it was ascertained that only one of them closed entirely. They were both found ajar after the discharge. The marks of their concussion against the salient of the nearest offset enlarged.

N.B.—The particular effect of this series of shots upon the shutters was to strain the straps of the hinges at the rivets nearest the eye, causing the shutters to bind against the gorge plate, and thus prevent their closing perfectly. It was probably occasioned by the blast taking effect partly behind them, through the opening between them and the gorge plate, and tending to force them from their fastenings. The striking of the shutters against the offset may have assisted in producing the same thing. The strain upon the straps of the hinges was confined almost entirely to the lower ones.

Before proceeding to the results of subsequent firings *at* the 1st target, it may be well to remark on those recorded in the table just given.

24 Upon this embrasure (No. 3), of which the outer cheeks were of cement-concrete on one side, and of brick work on the other, no injurious effect whatever was produced by the blast of the gun, when fired directly to the front, or when traversed as much as 30 degrees from the directrix; or when elevated 5 degrees—which was all that the embrasure would allow. In respect to the form, dimensions, and materials, of the embrasure itself, the results were perfectly satisfactory.

25. But it was not so with the shutters. These consisted of two leaves, and were found to be not strongly enough hinged to the vertical throat-irons. Nor were they truly centered on their hinges, even before they were deformed by the firing.

26. It was clearly shown, however, that shutters mounted like these, and as light—however it may prove to be with heavier ones—will, if well centered, always close spontaneously on the discharge of the gun, some device being necessary, however, to keep them from opening again, by rebound.

27. Moreover, subsequent firing against these shutters—which were made of "boiler iron" half an inch thick—proved them to be too weak to resist, without being deformed, and thereby rendered useless, any missile fired from a large gun, within a short distance, if harder and larger than a musket ball.

28. The tables 2, 3, 4, 5, 6, and 7* which follow, give the effects of firing against the 1st target with large and small canister shot; with grape shot; with musket balls in canisters; with spherical case shot; with solid shot, and with shells.

29. The terms "right" and "left," used in all the tables of firing *at* the target, mean the right and left hand, when looking at the target from the battery.

30. In the tables of firings *from* the target, the same terms mean the right and left hand, when looking out of the target embrasures, to the front, at the battery.

31. In figures, the single dash at top indicates feet—the double dash inches; for example, by 3′ 6″, is meant 3 feet 6 inches.

SECTION IV.

Instructions for Building 2nd target, and Remarks in relation to Materials used in the Construction.

32. Before proceeding to practical deductions from the experimental firings given in the foregoing tables, it seems best to give, in similar tables, the firings from, and at, the 2nd target.

The peculiarities of this 2nd target were partly consequent upon the results afforded by the trials of the 1st.

The following extracts from directions given as to this second target will, with the plates and figures, sufficiently explain the construction, form, and dimensions of all its parts.

LETTER TO COLONEL LEE.

Engineer Department,

" Brevet Col. R. E. Lee, *Washington, 5th May*, 1854.

Corps of Engineers, Superintendent and Commanding Military Academy, West Point, N.Y.

33. Sir,—The gunnery practice upon the embrasure target at West Point has afforded several important results in reference to the form, dimensions, and materials, proper for sea-coast embrasures; still there are some other matters not fully settled that are of not inferior importance—and before we draw up a final report to the Secretary of War, I desire your further assistance in clearing these from doubt.

* Omitted for want of space, the general results being given in Chapter 2.—Ed.

34. I now send the drawing of an embrasure to be made of granite and iron; and have to ask your aid in putting it immediately under construction.

35. There is nothing obligatory in the exterior granite appareil of the drawing, except of the embrasure itself; above, below, and on the sides, the courses may be arranged to suit stones on hand, or such as can be most easily procured.

36. The interior face, with the same exception, is supposed to be of bricks; it may be of rubble masonry.

37. The heart of the wall is to be of concrete, in the following proportions:—The measure of mortar to be twice the measure of void space—the latter being reduced to a minimum nearly, by the use of fragments of various sizes.

38. All the mortar should be composed of cement in dry powder—1 measure to 1 measure of clean sand—except in laying the stones or bricks composing the embrasure, and this should be of cement in paste 2, to 1 of sand.

39. All the mortar in which cement enters should be made at the moment of using it, and no cement should be used of which the test cake required more than a few minutes to bear the pound weight.

40. The drawing shows the outer and the inner sill-stones of the embrasure—the latter being connected with the stone beneath it by two cast-iron dowels which, besides being closely fitted to their holes, should be leaded, by pouring down lead through small holes drilled through from the top stone. These sill-stones, besides being prepared for the head of the pintle bolt, will have cut in them recesses for the lower ends of the cast and wrought iron jambs. This is the place to state that these jambs will be composed first, of a mass of wrought iron 4″ × 10″ and 3′ 3″ high, composed of eight thicknesses of boiler iron, fastened into one mass by a sufficient number of rivets; and secondly, of a mass of tough cast iron of irregular section (as seen in the drawing), and 3 feet 6 inches high, fitting tightly to the back of the wrought iron mass. These iron jambs being placed erect in the appropriate recesses, and accurately adjusted, will be leaded therein. You may find it advisable to interpose a thin sheet of lead between the two.

41. The figure shows the first course of cheek stones, as they embrace the iron jambs. The inner cheek stones embrace also, for a depth of six inches, the inner sill stones, and cannot be moved inwards without taking with them the sill-stone and a still larger stone beneath. These outer and inner lower cheek stones are connected by cast iron dove-tailed cramps 10 inches long and 2 inches thick—they are also prepared for connection with the second course of cheek stones by cast iron dowels. Pains should be taken to secure the tight and accurate fitting of all such dowels.

42. It will be noticed that there is to be a shutter of two leaves, to be made of three thicknesses of half-inch boiler iron. The form and dimensions are fully shown. It is to turn on two gun-metal pivots (one above and one below) imbedded in, and riveted to, the iron; which pivots fit accurately into composition boxes, firmly leaded into the sill and lintel. These shutters should be accurate in form, so that they may fit solidly against the proper surfaces when shut, and also when fully open; there will then be little danger of their being deformed when struck by any but a large shot. They should, moreover, be truly centered, so as to move with facility; for if this be the case, they may be expected to shut spontaneously, on the discharge of the gun. To meet this result, or at any rate to provide a simple mode of fastening, a gun-metal latch is devised to be placed at the lower corner of each leaf. The moveable part of this latch will rest on the sill of the embrasure when the shutter is open; as it closes, this part will rise over a gun-metal catch, firmly fastened into the stone sill: it will pass beyond the catch about an inch, so that there may be time for it to fall before reaction can send the shutter the other way.

43. You will notice a concave conical surface cut, at the throat of the embrasure, in the top of the outer sill; this will allow room for the tulip of the gun, as it traverses, when depressed.

44. In this embrasure, both the height and breadth of the exterior opening, and of the throat, have been materially reduced; and it would be a great gain to be able to adhere to these dimensions, which, it is hoped, may with care be done. It is in the throat where there must be the greatest accuracy; and it is hoped, moreover, that with attainable accuracy at the throat, there may be a still greater reduction of the exterior opening—this will depend, however, on the effect of the blast, when the gun is fully traversed. In this design, the ball will pass within about 1½ inches of the corner of the shutter and the outer edge of the embrasure; if we find this proximity does no harm, we may possibly approach still nearer To keep the ball from going nearer than it ought, and the blast from doing any unnecessary injury, it is dispensable that the axis of the pintle should be exactly right. But that alone will not be enough – there must be no room for play in the tongue of the carriage around the pintle—there should probably be a bushing fitted to the tongue hole, so that it shall embrace the pintle closely.

We may indeed even then find that the carriage is in itself untrue, to an extent forbidding so narrow a throat as we are about to try.

45. There are to be traverse circles laid foi this embrasure, because very important trials are to be made by firing from it with an 8-inch Columbiad. I need not say that these circles should be laid with exactness and solidity.

46. The exterior facing of the granite embrasure may be cut quite roughly; the facing towards the embrasure should be rather finely cut—the beds, and other surfaces in contact, should be truly cut, though not finely – that is to say, hollows of moderate size will be of no consequence. The contact of the granite with the iron jambs should be very carefully attended to, as also iron with iron; to which end, the rivets of the wrought-iron mass, and the shutters, should be countersunk flush.

47. The wall containing this embrasure may be the rebuilt portion of the granite end of the former target, and of the same height. I would, however, carry the granite wall as much as ten or twelve feet westward of the embrasure – building the inner face and heart, as before mentioned, as I desire to fire against a five feet wall of that construction, a few solid shot of large calibre under the highest velocity. Supposing you have no 10-inch Columbiad, I think the trial quite important enough for you to call at once for one to be added to your battery—ships are likely to use even larger guns than these.

48. It will be noticed in the section, that the wrought-iron jamb stands a little obliquely to the plane of the throat; this obliquity might be greater with advantage as respects support to this jamb from the interior cheeks of the embrasure; and without danger as to the deflection of small shot into the embrasure; but it would involve a form of shutter not favorable to resistance; even the slight inclination I have in this case given to the jamb requires, for a shutter at all arched outward, a little recess to be cut for it in each outer cheek.

49. I am in hopes that the form of the cast-iron backing will transfer any effect advantageously to the stone behind it.

50. The heads of the rivets of the pivots of the shutter should be countersunk on the side next the jambs, so as to be flush. Being put through from that side the shutters should then be closed, and then the outer ends be riveted down without any counter-sinking on that side; this will allow the shutters to be dismounted by merely cutting off these rivet heads. Of course there must be slight depressions cut in the granite to receive the protuberances.

51. I had an understanding with Lieut. Gillmore while he was here lately, as to many of these details, and should be glad if he could be charged with the duty of constructing the target.

52. The person in charge must observe the closest economy consistent with good materials and workmanship, using, as far as possible, the old materials, and also the labour of the engineer company.

53. I shall send shortly a drawing of a brick embrasure ; and I have ordered to be sent to West Point from Charleston (South Carolina) 3,000 of the kind of bricks used at Fort Sumter—these express very well the general quality of southern bricks ; and it is very important to know their value in the construction of embrasures, since that part of the country affords no durable stone.

54. In order the better to try the effect of heavy balls upon the masonry, it would be well to place the 10-inch gun at a distance not greater than 200 or 300 feet from the target, and I assume that this may be done without raising the gun much above the surface of the ground.

55. The platform might be now prepared. The firing generally to be from the old platform.

I am, very respectfully, Sir,
Your obedient servant,
(Signed) JOS. G. TOTTEN,
Brevet Brigadier General and Colonel Engineers.

LETTER TO COLONEL LEE.

ENGINEER DEPARTMENT,
Brevet Col. R. E. LEE, *Washington, 20th May,* 1854.
Corps of Engineers, Superintendent and Commandant Military Academy, West Point, N. Y.

56. SIR,—I now send plans, sections, and elevations, of an experimental embrasure, which I desire to have constructed by the side of the one of which I lately sent drawings *That* was to be faced, and generally constructed with granite. This will be generally of brick-work.

57. The stones around the pintle will be the same in both, as will be those in the sole, at the throat--excepting that in one of the latter the hinge and latch sockets will be omitted, as it will not be necessary to try the shutters in more than one case.

58 The inner portion of the sole may be formed of a thin flagging stone—the outer, of a flat inverted brick arch. The large wrought and cast iron masses will be the same as in the granite embrasure. Of iron, there will be, in addition, a wrought iron plate half an inch thick, bent around the small projecting portion of the cheek immediately in front of the throat, and kept in place, partly by two wrought iron anchors strongly riveted to the front face ; the sill-stone beneath must be cut away, so that the lower ends of these plates shall be about two inches below the sole. The embrasure at top will be closed by inner and outer brick arches.

59. It will be necessary to prepare this embrasure for a gun with the same accuracy as the granite embrasure, and lay behind it the traverse circles ; for we must try the effect of the blast of the gun in this case also.

60. Considering what is said above as sufficient in reference to the general construction of the embrasure, I proceed to the particular precautions to be taken in laying the brick-work.

61. In order that our test may have special results as regards bricks made in the southern part of the coast, where they have no stone of quality suitable for such uses, I have directed a sufficient number of good bricks to be sent to you from Charleston ; and it is with these Charleston bricks that I desire the embrasure to be built.

62. The best bricks of that market are very unsightly, and cannot be made into a handsome wall; but they are very durable, standing the southern climate better than our northern brick. They are thought, moreover, to adhere strongly to mortar.

63. The bricks used in the arches should not be cut into true voussoirs, but must fit their places by thin joints next the centre, and thicker at the extrados. It will not be necessary to bestow any particular pains on the appearance of the brick facing; but I wish every brick to be laid with the greatest care, as respects its connection with the mortar of the joints.

64. In the late firings against brick-work, from a 42-pdr., it was noticed that there was a separation of bricks from mortar very generally, as the limit to the breach caused by the shot; and it was certain that if the cohesion had been greater, the effect of the shot would have been materially less. The brick-work had nevertheless been laid under the direction of an experienced and very attentive officer—the bricks, though brittle, were hard, and the mortar was composed of cement and sand, without lime.

65. The want of cohesion was due, as seemed to me, beyond any doubt, to the interposition of dust, sometimes quite free, but perhaps more generally composing a layer slightly cohering to the body of the bricks. The process of laying must be to cause every brick to be thoroughly soaked in water, and to be laid the *moment it ceases to drip;* arrangements easily devised, will enable this to be done without extra expense: but I must caution you, that as this will be in some respects a disagreeable process to the masons, they will neglect it, or do it improperly, unless it be imperatively and perseveringly insisted on.

66. In order in some degree to compensate for the short time we are able to allow the new brick masonry to harden, I think the mortar to be used in the whole of the brick-work, including the brick embrasure, should be of dry cement two measures, to sand one measure. In other respects the mortar, concrete, &c., to be as directed in my letter of May 5th.

67. Keep all masonry in progress shaded from the sun.

68. I send also with this letter, plans, sections, and elevations of an embrasure to be faced exteriorly with concrete.

69. To form the iron throat of this embrasure, I wish you to have the wrought iron masses (eight inches thick), that were used in old Embrasure No. 3, repaired, leaving off the shutters. The lower ends of these masses will be received in the granite stones of the sills, and the upper ends built in the arches The throat being a little wider than before, the masses of the two sides will not unite at top or bottom; but this, for our present purpose, is of no consequence.

70. This embrasure is to have the same half-inch wrought iron plate enveloping the first projection outside the throat as the brick embrasure; to be secured in like manner.

71. Portions of this embrasure—the pintle stones, tongue holes, sill stones, inside cheeks, sill and arch—will be the same as in the brick embrasure, only the outer facing being of concrete.

72. The concrete *used in the facing of this embrasure* should be made of mortar composed of cement two measures, sand one measure—the quantity of mortar to be twice the bulk of the void space in the brick fragments, reduced to a minimum nearly, by the admixture of fragments of bricks of different sizes, from that of a duck-shot to that of a pigeon's egg, all finer particles being sifted out.

73. The concrete backing *generally* may contain coarse fragments, broken stones, or broken bricks, or clean gravel, or all or any of these mixed, from the size of six or eight cubic inches down to the size of a hazelnut or less—clear, however, of all sand or dust.

74. All the mortar made for this target, whether to be used in concrete or not, should be made by first mixing well together, upon a floor, a small quantity of dry cement and the due proportion of sand; then quickly adding the necessary water at the moment it is about to be used, whether in concrete or masonry. Concrete should have the mortar added to the stone fragments as soon as it is made, and just as the concrete is to be applied. In other words, the first setting of the cement, which when it is energetic and good is very prompt, should not happen, even partially, until it is in place, and not liable to further disturbance. If this practice cannot always be accurately followed, it should always be aimed at, and adhered to, as far as practicable.

75. Some of the mortar used in the concrete (somewhat diluted perhaps) should be smeared over the surface with which the concrete is to be in contact, the concrete being rammed in before this stucco has hardened: this is especially necessary on the sides of wooden moulds—which, moreover, if they have not been painted, should be made very wet.

76. While the concrete embrasure is under construction it should be kept shaded, and as soon as it is finished, should be stuffed full of wet grass or hay, and then a thickness of the same applied to the vertical surface,—all being kept wet, the longer the better.

77. From the centre of the concrete embrasure No. 9 to the end of the target, ten feet, the facing should be of concrete, the corner being protected by brick blocking.

78. From the centre of the same, for a distance of thirteen feet towards the brick embrasure (No. 8), the facing will be of good northern bricks (avoiding the very brittle kind used in the old target), as will be all the brick-work in connection with the concrete embrasure.

79. For a distance of seven feet on one side and ten feet on the other of the brick embrasure (No. 8), the facings will be of Charleston bricks, as well as all the other brick-work of the embrasure.

80. Embrasure No. 7 will be faced for ten feet on each side with granite.

81. A former letter refers to the manner of facing the interior of the target.

82. A light wooden cover should be put on the top of the target to keep out rain.

83. It is important that this target be made ready for the proposed tests as soon as practicable.

I am, very respectfully, Sir,

Your obedient servant,

(Signed) JOS. G. TOTTEN,

Brevet Brigadier General and Colonel Engineers.

84. The interior facing of the wall was rubble work, stones rather small.

85. The heart was of cement-concrete (without lime) composed of gravel and broken fragments of northern bricks and of stone, varying in size from pieces containing six or eight cubic inches down to that of a pea, sifted clear of sand and dust. The amount of mortar in this concrete was equal to twice the volume of void space in the mixed fragments, and was composed of cement measured in powder, and sand, in equal parts. All the mortar of the target was mixed with these proportions of cement and sand, except for the stone, brick, and concrete work, composing the embrasures themselves, which contained cement in paste *two* to sand *one*. The amount of this mortar in the fine concrete for Embrasure No. 9, was equal to twice the volume of void space in the broken fragments—the fragments being well soaked in a cream of cement immediately before mixing. To the left of the axis of No. 8, the fragments in the concrete composing the heart of the wall were soaked in a similar manner. One half of the northern bricks and a like proportion of the southern were dipped in a cream of cement just at the moment of laying. In the wall, the portions of the two kinds of brickwork thus treated join each other.

SECTION VI.

Remarks as to Condition, Comparative Strength, &c., of the Two Targets.

86. In noting the effects of firing upon the masonry of the first target, it was plain there was not so great a degree of cohesion between the mortar and other materials as had been expected from the pains taken in the construction. Whatever may have been the cause, this was made very evident by certain results in the course of the firing; and it induced more than common care, as to materials and workmanship, in the construction of the second target.

87. As to comparative strength and solidity, therefore, the first target may, probably, be regarded as in no degree superior to walls of the same materials and age, in fortifications generally.

88. While the second target, constructed with strict conformity to the instructions before quoted, was probably somewhat better than such walls.

89. Both were, however, much inferior in hardness and cohesive strength to what they would have become, even in some ten or fifteen years. And it is worthy of consideration that the brick, and the concrete portions, were much worse off in this particular than the part formed of granite blocks, since the importance of time, as an element of strength in constructions of this nature, is the greater as mortar enters in the greater proportion—that is to say, is of much more importance in brick masonry, or in concrete, than in stone masonry, or at any rate in coursed stone masonry; in the latter, its importance being inversely as the magnitude of the individual stones, that go to make up the wall.

90. The shutters of Embrasure No. 7 (2nd target), though pretty well hung, were not perfectly centered; and the friction was therefore too great for them to close entirely by spontaneous movement, on the discharge of the gun—although one leaf closed, and remained shut, in one instance. The same leaf was about half closed by each of the other discharges; while the opposite leaf, more imperfectly centered, was found each time moved out only one or two inches from the cheek of the embrasure. When the gun was depressed about 4°, and trained at the same time about 30° away from the directrix, some injury was done to the shutter-catch on that side, owing to weakness in its confining bands.

91. On the whole, there is no reason to doubt that shutters like these in the second target, heavy as they are, may be caused to close, of themselves, at each discharge. They must, however, be truly centered, and have strong and freely moving hinge-pivots and latch. A stiff spring, acting on the back of each shutter, would, at any rate, insure the closing.

92. The mortar in the interior of the masonry and concrete of both targets, as exposed in the breaches, was, although to a certain degree solid and hard, decidedly damp, not to say wet—as was plainly shown by the darker colour of the inner portions, and as was evident to the touch.

93. Both targets were quite new—the time intervening from the completion of the first to its destruction, being about fifteen months; and with the second, about thirteen months.

94. A close examination of the different kinds of masonry in the second target, after the firings had ceased, elicited the following facts, as reported by Lieutenant Gillmore.

1*st*. The adhesion of the concrete to the brick-work was greater than to the stone-work. The difference appeared to be considerable, and any material deviation from this result could always be traced to imperfect manipulation. Some of the irregular fragments of the wall broken off by the heavy shots, and containing from one to two cubic feet, were composed of brick-work on one side and concrete on the other, connected by a vertical plane surface joint, and after falling to the ground from a height of 8 or 10 feet remained unbroken. Of the two kinds of brick-work, the adhesion to the concrete proved to be largely in favour of the northern brick.

95. *2nd.* In the body of the concrete, the adhesion of the mortar to the brick fragments was somewhat greater than to the stone fragments. The adhesion to the gravel which was rather smooth, and to the rounded stones placed in the different layers, was rather slight. It was found that, with every precaution, the junction between the masses of concrete made on different days, was always considerably less firm than between the consecutive layers made on the same day; and the fractures from firing generally took place along these principal planes of division, first. Where the concrete formed a portion of the face of the wall, the termination of each day's work could generally be readily traced with the eye.

96. *3rd.* The fine concrete of Embrasure No. 9 was somewhat stronger than that adjacent to it on the face of the wall, though not to the extent which the double quantity of cement, which it contained, might lead us to expect.

4th. The adhesion of the mortar to the brick-work appeared somewhat greater than to the stonework. It was difficult, however, to institute a comparison between these two kinds of masonry, from the greater ease with which the brick-work could be examined.

5th. The adhesion to the mortar was greater in the northern brick than in the southern. In the former, indeed, this quality was quite remarkable, overcoming in many cases the strength and tenacity of the brick itself, when it was attempted to separate a joint with a chisel or hammer. In such cases generally the surface of separation after following obliquely for some distance the mortar of the joint, would branch off into the brick, giving in the two materials a continuous conchoidal fracture. In both kinds of brick-work the mortar appeared to be harder and stronger in proportion to its proximity to the face of the wall, indicating clearly that a longer time, and a more complete evaporation of the moisture in the wall was necessary for the mortar to attain its maximum strength and hardness. The same may be said of the concrete.

97. *6th.* The adhesion of mortar to brick in the horizontal joints was thought to be somewhat greater than in the vertical ones, though to a very small extent. In laying up the brick-work every precaution was taken, and as this final examination showed with complete success, to secure the most perfect contact and the maximum density in the vertical joints, by using plenty of mortar, and forcing each brick well up towards those adjacent to it.

98. *7th.* In the horizontal joints, no difference could be detected in the adhesion of the mortar to the bricks below, as compared with those above.

8th. It did not appear that soaking the bricks in cream of cement gave better results than soaking in pure water. When the latter method is employed, the process loses much of its virtue, unless the bricks are laid as soon as they cease to drip, and before the film of water has left the surface; with a stiff mortar it was found that much better contact could be secured when the brick was quite wet at the moment of laying.

Thoroughly soaking the bricks will not suffice, unless they are laid with the free water upon the surface; if such be not the case, the mortar should be quite thin to insure a perfect contact; but by making it thin, its ultimate density is impaired.

99. *9th.* It did not appear that the concrete was improved by soaking the solid parts in cream of cement instead of water.

CHAPTER II.

Effects of the Firings upon the Different Materials Used in Building the Several Embrasures of the Two Targets.

SECTION I.

Effects of firing from 42-pdr. and 8″ Columbiad, with Iron Canister Shot of $1\frac{1}{2}$ *lbs.; 6·88 oz.; 5·10 oz.; and 3·33 oz.—distance 200 yards.*

100. *Upon granite.*—Generally no effect: when striking near edges or solid angles, producing cracks, knocking off pieces of stone, and driving several small fragments through the embrasure; a piece broken off 8″ by $1\frac{1}{2}$″ by several inches in depth; another 15″ by 4″ by 4″.

101. *Upon brick-work.*—Holes were made in the brick facing, varying in depth and diameter with the size of the shot, the penetration being a little greater in the southern than in the northern bricks. Pieces were broken from edges; a piece 5″ by 4″ by 3″ broken out of arch.

102. *Upon cement concrete.*—Holes made in the face of the concrete—diameter 6″ to 10″, depth 2″ to 4″. When a shot struck upon, or near, a solid angle, an irregular mass was knocked off from 6″ to 16″ in length, by 2″ to 8″ in breadth and thickness.

103. *Upon asphaltic concrete.*—Holes made in the face 5″ to 7″ diameter by about 2″ depth. One mass knocked off a solid angle, 7″ high by 4″ broad; another, 17″ by $5\frac{1}{2}$″ broad. A shot struck 4″ from edge of asphalte, producing cracks 7″ to 8″ long, extending to edge.

104. *Upon lead concrete*—Holes equal, about, in width and depth to the diameter of ball—no cracks, and no fragments of any size thrown off.

SECTION II.

Effect of firing from a 42-pdr. and 8-inch Columbiad, with grape shot of 4·20 lbs. each—distance 200 yards.

105. *Upon granite.*—Generally no effect. One shot cracked off the corner of a granite block 8″ or 10″.

106. *Upon brick masonry.*—Craters were produced in the face about 8″ in diameter and 4″ to 5″ deep. At junction of brick and cement concrete the hole was 15″ in diameter by 3″ deep. Shots struck near solid angles with various effects: generally, a few pieces of bricks were broken off. In one case the effect at the end of the target was considerably greater.

107. *Upon cement concrete.*—The holes in the face varied in diameter from 12″ to 15″, and in depth from 3″ to 4″. There were various effects according to circumstances.

108. *Asphaltic concrete.*—Was not struck.

109. *Upon lead concrete.*—An impression was made equal in depth to $\frac{2}{3}$ the diameter of the ball, and of a diameter equal to that of the ball, which was not broken; no fragments beyond mere spiculæ thrown off, and no cracks.

SECTION III.

Firing from a 42-pdr. and 8-inch Columbiad, with musket balls as canister shot—distance 200 yards.

110. Produced no effect upon any of the materials—the leaden musket balls being flattened upon all.

SECTION IV.

Firing with 42-pdr., spherical case shot filled with musket balls—distance 200 yards.

111. *Upon granite.*—When granite was struck before the bursting of the shell, the effect was considerable—pieces being broken off—cracks produced—joints opened, and motion caused in joints.

112. *Brick masonry.*—Was not struck.

113. *Upon cement concrete.*—When a solid angle was struck, the effect was considerable—pieces, sometimes of large size, being knocked off.

114. *Upon asphaltic concrete.*—A shell striking perpendicularly on the face, produced a crater 2 feet in diameter and 7 inches deep. The bursting caused no further injury. The embrasure was still serviceable.

115. *The lead concrete*—was not struck.

SECTION V.

Firing from a 42-pdr. with loaded Shells—distance 200 yards.

116. *Upon granite.*—The granite blocks near the right top course being struck, were considerably displaced.*

117. *Upon brick masonry.*—A crater was formed 2′ in diameter and 1′ deep; shell broken by the concussion.

118. *Upon lead concrete*—A crater was produced 1′ 4″ wide and 8½″ deep. The shell exploded in the crater—no cracks, and none but minute fragments sent off from the lead.

119. *The rubble masonry, cement concrete,* and *asphaltic concrete*—were not struck.

SECTION VI.

Firing from a 24-pdr. with solid shot—distance 95 yards.†

120. *Upon cement concrete.*—Ball, striking not far from left end and top of target, penetrated 1′ 10″—crater about 3′ 6″ in diameter, extending to top—cracked the wall through, and out to the end—ball did not break.

121. Another, struck a little lower, entered 1′ 3½″, diameter of crater 2′ 6″—made a crack out to the end (about 5 feet).

122. Another, penetrated (about 10″) to the outer sill stone, which it cracked slightly, as well as the inner one, without displacing either—cracking and disturbing a little the brick-work and iron-work of the throat of the embrasure.

123. Another ball struck below Embrasure No. 9, at the junction of the cement concrete and brick-work, passed through a thickness of 2 feet, into and through the tongue-hole, which was 7 inches high: did not touch its top, bottom, or sides, carried away a mass of concrete in front of the sill, which it cracked but did not disarrange.

124. Other shots from the 24-pdr. aimed chiefly at the iron-work of the embrasure, broke away more or less of the contiguous concrete and brick-work. Effects upon the iron-work to be stated further on.

SECTION VII.

Firing from a 42 pdr. with solid shot—distance 200 yards.

125. *Upon granite.*—The craters formed in this material by shots striking perpendicularly, were of irregular form—from 1½ to 3 feet in diameter, and in depth about 4 inches. When the balls struck near edges, fragments, sometimes large, were broken off; and in some cases fragments of the stone and of the shot, passed through the

* A shell without a fuze was fired against the granite and exploded on striking.—Ed.

† This was probably 200 yards, as it is so stated in the tables.—Ed.

embrasure, tearing away large portions of the screen behind. Moreover, cracks were thrown off to a considerable distance from the point struck, often entirely through the largest stones. Joints were opened for some distance. The balls were generally broken.

126. *Upon rubble-work.*—The interior rubble facing of the target, which was of rather small stones, and not well tied to the wall by headers, was started inwards in one or two cases, and was frequently cracked and jarred.

127. *Upon brick-work.*—When the ball struck the wall perpendicularly, the craters formed were in diameter about 2′ 6″ and in depth from 1′ 6″ to 2′. Where the rear lining of the target was of brick-work, the portion behind the crater was considerably cracked and jarred. The greatest effect was produced by shot No. 65,* Table No. 7, (which see). The balls generally did not break.

128. *Upon cement concrete.*—The effect was great, particularly when the balls struck near a solid angle; considerable masses were then broken off; cracks were generally produced, with a shattering of the material. Balls sometimes broken and sometimes not.

129. *Upon asphaltic concrete*—Effects very decided. The concrete was either removed entirely when struck, or very much cracked and shattered.

130. *Upon lead concrete.*—The effect was very favourable to this material; the penetration was 12 inches, and the diameter of the crater from 14″ to 15″, of very regular form—no fragments of any size—no cracks. The balls were broken and stopped.

SECTION VIII.

Firing from 8-inch Columbiad, with solid ball of 68 lbs.—distance 200 yards.

131. *Upon granite.*—When the stone was struck directly, as in 203, 209, Table No. 15, the effect was great, fragments of stone being broken off, sometimes large, and carried through the embrasure with much force—extensive cracks being produced, and joints opened and disturbed in the vicinity of the point struck, both on the inside and outside of the wall. When the irons were struck, the granite in contact with them was broken, cracked, and shattered—joints being opened or jarred in some instances for a considerable distance from the point struck. The balls were generally broken, and passed through the embrasure in fragments, tearing away, with pieces of stone, large spaces from the screen.

132. *Upon brick-work.*—A considerable crater was produced by striking this material. Generally the effect seemed confined to the immediate vicinity of the point struck; although in some cases there were pieces of the brick wall broken off, and cracks produced on the inside as well as on the outside of the wall.

133. *Upon cement concrete.*—The penetration seemed to be about two feet. Cracks were formed, extending for several feet in different directions. The material was much shattered at, and near, the point struck. When striking cement concrete alone, the balls were not broken generally.

134. *Upon rubble masonry.*—This was not struck in this firing, but the effect of the ball was, in many cases, transmitted through the wall, and where the inner face was of rubble, caused cracks therein, and occasionally threw off small portions that were not well tied in.

135. *The asphaltic concrete* was not struck in this firing.

* The effect of this shot is thus described in the Table.—Ed.

"Shot struck about 8 in. from the edge of the opening, penetrated 1 ft. 10 in., knocked off a mass of brickwork 3 ft. 6 in. high, and 2 ft. 2 in. broad; also the head of the arch was knocked off to the depth of 10 in. and height of 1 ft. 5 in. From the crater, extending to the end of the wall, the brickwork was entirely shattered, large cracks extending diagonally to the top of the wall and horizontally to the end. On the inside of the throat a great deal of the arch fell in, and large cracks were made in the stonework in various directions. The brickwork about the throat was much shattered."

SECTION IX.

Firing from 10-inch Columbiad, with solid balls of 128 lbs.—distance 114 yards.

140. *Upon granite.*—The penetration in granite was from $7\frac{3}{4}$ to 10 inches—the effect was to shatter, crush, and crack in all directions, the stones at and near the point hit. Joints between the granite blocks were opened, sometimes as much as four inches. In the firing two of the blocks near the point of impact were, by reaction, brought out 2″ or 3″ in a direction opposite to the shot's motion—that is to say, towards the gun. The effect upon the surrounding bond was much less—indeed, it was quite slight in directions where there was firm support, that is, towards the foundation, and towards the left—than upwards and towards the near right end of the target. Some rubble-stones in rear of the points struck were knocked out of the rear facing.

141. *The rubble* was not hit by these balls; but when it formed the inner facing of the target, behind the point of impact, it was started from its bed, and sometimes stones were thrown entirely out.

142. *Upon brick-work.*—Although the local effects in this material appeared to be considerably greater than in granite, the general effect was less wide-spread; but this may have partly, at least, been due to its being supported on both sides, while the granite was sustained, on one side only, by much masonry. There was no apparent difference as to resistance, between the northern and southern bricks. In one case, the ball* passed entirely through the wall. But it is essential to bear in mind, as to all these effects, that the target was then very much shattered by previous firing. Of course the resistance to many of these heavy balls was considerably less than it would otherwise have been.

143. *The cement concrete* was not struck by any of these 10-inch balls.

CHAPTER III.

EFFECTS OF FIRINGS UPON THE IRON SHUTTERS, THE IRON FACINGS, AND THE IRON THROAT-PIECES OF THE EMBRASURES.

Effects upon the Shutters of $\frac{1}{2}$″ boiler iron, produced by musket balls, canister shot, and grape shot, fired from large guns within short distances.

144. *Musket balls* produced no effect.

145. *Canister shot,* weighing 5·10 ounces, made a rather slight indentation. In one case the plate of iron was cracked open. In another, a piece one-half the size of the ball was cut out of the edge; and in another, the hinges were broken or strained.

146. *Canister shot,* weighing $1\frac{1}{2}$ lb each, produced in these shutters depressions from $\frac{1}{2}$″ to $\frac{3}{4}$″ deep—one shot caused a crack.

147. *Grape shot,* of 4·20 lbs. each (diameter 3″·17) passed through, or entirely carried away, these $\frac{1}{2}$ inch shutters.

148. *A spherical case shot* struck one of these $\frac{1}{2}$″ shutters, and cut out a segment 9″ high, and $2\frac{1}{2}$″ broad; but the shutters were notwithstanding left on their hinges.

SECTION II.

Effects of firing upon the Shutters $1\frac{1}{2}$ inch thick, composed of three plates of $\frac{1}{2}$-inch boiler iron, well riveted together.

149. *Canister shot, weighing 3·33 ounces,* made only a slight indentation on these shutters, one shot striking the latch, disabling it temporarily.

150. *Canister shot, weighing $1\frac{1}{2}$ lb.,* produced indentations $\frac{1}{4}$″ to $\frac{1}{2}$″ deep, and $1\frac{3}{4}$″ in diameter. One shot broke off horizontal portion of the latch.

* "This ball struck about $3\frac{1}{2}$ feet to the left of No. 8, in line with the sole.—ED."

151. *Grape shot weighing* 4·2 *lbs.*—Made an indentation 4″ diameter and ⅝″ deep; the shutter was slightly bent; the shot was broken and stopped.

152. *Solid shot of* 68 *lbs.*—The shutters, being open, were struck, in one case upon the offset, in the other upon the edge. In both, the shutters were much injured and disabled.

SECTION III.

Effects Produced upon the Boiler Iron Facings (½-inch thick) of the Offsets of the Embrasures, by Musket Balls and Canister Shot.

153. Musket balls and canister shot, varying in weight from 3·33 oz. to 1½ lb., produced no injurious effect—that is to say, when the offsets of the embrasures were thus covered, no fragments were broken from them and carried through the embrasures, as was the case from unprotected facings of stone, bricks, or cement, or asphalte concrete. The indentations in these iron plate coverings of half an inch in thickness, made by the 1½ lb. canister balls, were from ¼″ to ¾″ deep and 1½″ in diameter.

154. In no instance were these half-inch coverings struck by grape shot.

SECTION IV.

Effects Produced upon the 2-inch Offset Plates of Wrought-Iron Inserted in the Outer Cheeks of Embrasures Nos. 4 and 5.

155. A 42-pdr. ball struck one of these 2-inch plates, broke a piece out of it, and jarred the whole of that cheek; it was itself broken thereon. Another struck the left throat plate, also two inches thick, cutting out a piece about ⅓ the area of the ball, which passed on; it, besides, bent the plate a little, and jarred it in its position. Another struck an outer offset plate, broke a piece out of its middle, passed on, and was stopped by, and broken on, the second plate, which was uninjured.

SECTION V.

Effects of Firing upon the Wrought-Iron Throat-Pieces.

156. The throat-pieces of Embrasures Nos. 3, 4, 7, 8, and 9, stopped musket balls, canister shot of all sizes, and also grape shot of the weight of 4·2 lbs., no effects being produced upon them, except unimportant indentations.

157. A 42-pdr. spherical case shot, weighing 39 lbs., struck shutter No. 3, near its junction with gorge plate, indented the plate to the depth of about 2½ inches, and caused a considerable bending of the whole plate.

158. A solid shot from a 24-pdr., distant 95 yards, was well resisted and entirely stopped, by the throat plates of No. 9. But after several shots had struck the same plates, the injury was considerable—the final result being the entire removal of the plates.*

159. Some 42-pdr. solid shots, striking gorge plates of No. 3 and 4, bent them, and finally tore them from their fastenings.

160. The throat plates of No. 8, on being struck two or three times by 68 lb. solid shot, were carried away, the cast-iron backing being cracked and having pieces broken off.†

* "The embrasure, however, continued serviceable."

† The first "struck the left throat-plate 4½ inches below the top, lapping on the plate about half the diameter of the ball, and was deflected to the right, breaking out small segments from 4 of the plates, and bending the inner plate 1¾ inch."—Ed.

161. A 68 lb. ball, striking the right shutter and throat plate of No. 7, was broken into many pieces, impressing the throat plate to the depth of $1\frac{1}{4}$ inch, but not displacing it—destroying the upper part of the shutter.

162. Another 68 lb. ball striking the left shutter of No. 7, destroyed it, was itself broken, and deflected in fragments by the resistance of the throat plate, which was but little disturbed.

163. Another ball of the same calibre struck the same throat plate, and was deflected from it.*

164. Another 68 lb. ball was received by the same throat plate.

165. Still another, which carried it away.†

166. Another struck, with about half its diameter, the left throat plate of No. 8, near the top, cut out a portion, broke off some fragments from the thin plates of which it was composed, was deflected—did not materially disturb the position, or change the form of the throat plate.

167. A 68 lb. ball was broken on the left inner edge of the left throat plate of No. 8, doing little injury to the plate, but forcing it into an inclined position in the throat of the embrasure – this movement of the throat plate in its own plane was partly owing to the damaged state of the embrasure.

168. The next shot hit, and carried entirely away, this throat plate.

169. Another of these balls penetrated between the right throat plate of No. 8 and the brick-work, carrying the throat plate through the embrasure.

CHAPTER IV.

Experiments upon the Effects of the Blast of Guns.

SECTION I.

170. The course of the preceding experiments having shown, more and more clearly, the great advantage of a reduction in the size of the opening of the embrasure at the throat, as well as at the exterior face of the wall, some attempts were made to measure the cone of the blast at the mouth of the casemate gun, as it was important to know how near the path of the ball the solid angles forming the throat might be brought, without danger of being deformed or destroyed by the blast of the discharge—these solid angles being, even in the most oblique direction of the gun – namely, 30 degrees from the directrix—only $2\frac{1}{2}''$ inches in advance of the plane of the muzzle.

171. On some suggestions from the chief engineer, the following experiments‡ were therefore made at West Point, in August, 1855, under the direction of Major J. G. Brainard, of the corps of Engineers, then Superintendent of the Military Academy, who committed the execution to Major Fitz John Porter, of the Artillery, and Lieut. Donelson, of the Engineers.

* It is stated in the Table that "this ball struck the left throat-plate $11\frac{1}{2}$ inches below the roof, overlapping the inner edge of the plate somewhat more than half the diameter of the ball; and cut a segment from the outer plate 9 inches high by 5 inches broad, and small pieces from the two adjacent plates: it penetrated and bent the plate $4\frac{1}{2}$ inches before it glanced off."—Ed.

† The Table shows that after the lintel and throat-pieces of embrasure No. 7 had been struck by *seven* 68-pdr. shot it still continued serviceable.—Ed.

‡ Detailed in Table 17 (which is omitted here for want of space), the result being that the greatest "angle of flare" of a 42-pdr. gun was found to be 69° 26′ (measuring the surfaces blackened by the explosions.—Ed.

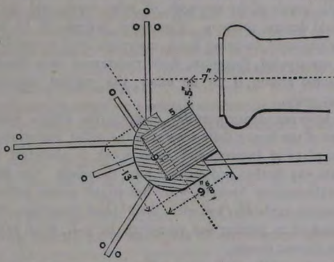
SECTION II.

172. Some further experiments of the same nature were next tried by the same officers—receiving the blast of a 24-pdr. gun on one of the wrought-iron throat plates that had been used as a throat plate in an embrasure of the masonry targets just demolished.

173. In order to this, a chesnut log, having the dimensions given in Fig. 65, was hollowed out to receive the two sets of iron plates—each set composed of eight half inch sheets—which were secured in their position by wedges. The log was then set upright in front of the gun, so that the edges of the plates* should be at the distances given in Fig. 65 from the muzzle and axis. The lower end of the log was buried a foot and a half in the parapet of the battery at the dock, and earth well rammed around it; and it was braced at top and near the ground.

These two plates, considerably distorted by previous firings, were the only ones not entirely ruined.

Fig. 65.



EFFECTS OF THE BLAST OF A 24-PDR. UPON WROUGHT IRON THROAT PLATES.

Gun 24-*pdr.*, *length* 10′ 4″, *weight* 5,790 *lbs.*, *charge* 6 *lbs.*

1st round.—Tore off the bark on the outside of the log. Loosened a piece of wood which was between the two sets of plates. Separated the 1st outer sheet from the 2nd sheet, $\frac{1}{8}$″ from the top, three-quarters of the way downwards. Also in the same way, the 5th from the 6th, one-sixteenth of an inch.

2nd.—Split the log half through; separated the 2nd and 3rd, and 7th and 8th, one-sixteenth of an inch from the top, half way down; separated the two sets of plates, so that there was a space between them of $1\frac{1}{4}$″ at top, 1″ in the middle, and $1\frac{1}{2}$ inch at the bottom. They were previously separated by a board about half an inch thick.

3rd.—Split the log almost entirely across, the split being $1\frac{1}{4}$″ wide in front. Separated a little more from each other the sheets before opened. Separated the two sets of plates, so that the interval between them was $2\frac{1}{4}$″ at top, $1\frac{1}{4}$″ in the middle, and $1\frac{3}{4}$″ at the bottom.

4th.—Split off outer piece of the log entirely, but did not blow it away; displaced the braces *c* and *d*, Fig. 65 Separated outer sheet from the rest, and threw it 30 feet to the front in the water. Separated the 2nd sheet from the 3rd, so that the interval was one-fourth of an inch at top, and one-sixteenth at bottom. Separated the first four sheets of the second set, so that each two were $\frac{1}{8}$″ apart in the middle. Separated the two sets of plates so that they were $3\frac{1}{4}$″ apart at top, $2\frac{1}{4}$″ in the middle, and $2\frac{1}{2}$″ at the bottom. The head of the rivet at *a*, Fig. 65, and 2 inches of the outer end of the rivet at *b*, were broken off.

* These throat plates were 39 inches high, and the axis of the gun was $14\frac{1}{2}$ inches below the tops of them.—ED.

CHAPTER V.

General Remarks and Conclusions.

SECTION I.

Conclusions as to the Effects of various Missiles upon different Materials of Embrasures.

174. It would be improper to deduce strict conclusions from these firings, as to the respective resistances to heavy balls, afforded by granite, brick-work, and cement concrete, since a few months only had been allowed for the mortar, on which the strength of the last two depends, to harden. Walls of well jointed, large stones would receive but little additional strength against a force of this nature, by the induration of its thin joints of mortar; while much of the strength of brick-work, and all the strength of cement concrete, would depend thereon. The short periods of 15 months, and 13 months, could not be expected to bring these materials into comparison with granite in this respect. As anticipated, therefore, their resistances were decidedly less; and of the two, for the same reason, if for no other, the cement concrete proved to be weaker than the brick-work.

175. There were, however, some peculiar comparative effects worth mentioning. For instance the force of the heavy balls seems, in the softer materials, to be felt only at, or very near, the place of impact, and, so to speak, is absorbed there—the ball, unbroken, crushing its way further and further into the mass. On the granite, however, these balls were themselves broken, with but slight actual penetration into the stone, throwing off cracks certainly, but with little local crushing—the remainder of the force being disposed of in jarring and vibrating the wall, to an extent that started from their beds quite distant stones.

176. From this vibration of the wall, so much more energetic in the granite portion of the targets than elsewhere, rubble-stones of the inside facing—not always directly behind the point struck—were thrown out by the first motion of the wall, as pushed over by the ball; and three or four stones were moved out of their beds, *towards the gun*, so as to project three or four inches from the plane of the wall, being left behind by this first motion, or projected forward by the returning motion of the wall—stones, moreover that were well jointed, well bedded in mortar, and of the dimensions of about 3′ by 1′ 6″ by 1′ 6″—while there was also considerable disturbance of all the other stones quite out to the right (the nearest) end, and up to the top of the target. This motion of the granite stones was very slight downward, where the target was supported by the earth on which it rocked; or to the left, where the stones were bonded into a considerable length of brick-work and concrete. The energy of these vibratory movements was very great, as the effects demonstrated; and though the space moved through was no doubt small, it might have been measured, had anything so marked been foreseen and provided for.

177. The heaviest of the balls fired (weighing 128 lbs.) penetrated, as above stated, a little way only into the granite blocks; but even the smallest of the cannon balls, namely, 24-pdrs., caused, as well as the larger ones, at the first blow, cracks that extended in several directions entirely through the stones hit. It was so with the larger blocks, as well as with the smaller ones—the succeeding balls finding these stones in a condition to be easily reduced to small fragments and dust. It may be expected, from effects of this nature observed, that under the impact of heavy balls,

with high velocities, these cracks, though perhaps scarcely perceptible at first, will extend as far as the crystalline continuity is unbroken—that is to say, to a joint, or quite through the largest stones that happen to be hit; and hence there will not probably be the additional resistance afforded against such battering, by the use of very large stones, as their appearance would seem to promise, or as would justify much additional expense in providing inordinate sizes.

178. There is no doubt, however, that concretionary stones, as "sand stones," would exhibit, under such trial, less brittleness than those of crystalline structure. Very large dimensions are more advantageous, in some other respects, perhaps, than in this.

179. The balls, whether large or small, that struck the granite under an angle that deflected them, unless the angle was very acute, were broken into many pieces, all of which passed on. If not deflected, they were crushed up into a mass of slightly cohering fragments and fine particles. In several instances, grape, or canister shot, striking the oblique cheek of a granite embrasure, were broken into numerous fragments, all of which were deflected in, through the throat of the embrasure—several having force enough to pass through the boards of the screen—very many smaller pieces and spiculæ burying themselves more or less in the wood, with a force that would cause serious wounds in human flesh.

180. It was seldom or never that a large ball was broken, on striking either brick-work or cement concrete. In one instance, a grape shot, on hitting the oblique cheek of a brick embrasure, was broken into two pieces that were reflected through the screen. In all others, when thus thrown off from bricks or cement concrete, they passed on through the throat and through the screen—making only one hole each in the latter.

181. The injury done to these oblique cheeks, by these smaller balls, was of no consequence, with either of the materials above mentioned. In reference to this particular point, therefore, namely, protection from small missiles—brick-work and cement concrete are better materials, very decidedly, for the faces of an embrasure of the established form, that is, with flaring exterior cheeks, than granite, or any other very hard substance.

182. From all the exterior embrasure-facings, except that made of lead concrete, when grape or canister shots struck near the margin of the opening, considerable, and sometimes numerous, fragments were torn from the facings and thrown into the embrasure, and, when the cheeks were flaring, through the throat and against the screen. Though the granite was in this respect the best material of the three, effects of this kind were, nevertheless, quite serious from it also. In one instance pieces were torn off by a grape shot from the lower edge of the lintel, for a length of two feet, and with a cross section of some six or eight square inches—the pieces being thrown through the throat. All the embrasures were considerably changed in their outline by injuries thus inflicted; and there was no point more clearly established by the firings than the necessity of protecting, from small missiles, the external margins of all masonry embrasures, by plates of wrought iron or some other device. This will be necessary with any form of embrasure, but more especially when the outer cheeks are so inclined as to reflect all fragments through the throat.

183. Plates of half-inch boiler iron were found to protect perfectly the offsets in the cheeks of the brick-work and cement-concrete embrasures, and may therefore be relied on to defend the external margins from these injuries.

184. The asphaltic concrete was brittle, under the action of even the smaller balls, to an unexpected degree, although the season of trial was summer. And in other respects it did not compare with either of the other materials. It could hardly have been relied on to retain its form, had it been made softer, by a larger proportion of bitumen. It may, nevertheless, be useful in special applications about embrasures and loop-holes.

185. Next to wrought iron, lead concrete proved to be much the best of the materials under trial. The first use made of it, in constructions, so far as I know, was by Major R. Delafield, of the Corps of Engineers, United States' army, in forming the exterior cheeks of casemate embrasures. Although less resisting, and more costly than wrought-iron, it is an admirable material for certain parts of embrasures; because, while it is very resisting, and will not crack nor splinter, it can, with the utmost facility, be applied to the filling solidly, of irregular spaces, and to the reinforcing of weak places, not easily strengthened otherwise. Heavy balls, under high velocities, penetrate into it a little more than their diameter, moulding for themselves a symmetrical bed, in which they are found crushed. They send no cracks through the mass; they detach no fragments—none at least that are not very small and harmless; they form a tulip-shaped crater, the outer edges rising above the general front surface, and curving gracefully away. The adjoining masonry is somewhat jarred, but in this respect the injury is as small as it can be in any combination. Grape shot (of the weight of 4½ lbs.) produce, on a small scale, effects just like those of cannon balls—so do canister shot. Neither grape nor canister shots were broken thereon. No balls, as it chanced, were deflected from it.

186. Some important conclusions may be drawn from the results with wrought-iron.

1st.—It may be fairly assumed that a plate, eight inches thick, of wrought-iron* of good quality, kept in place by a backing of three feet of strong masonry, will stop a solid ball from an 8-inch Columbiad fired with 10¼ lbs. of powder, from the distance of 200 yards. The plate of iron will be deeply indented at the point of impact, the ball carving for itself a smooth bed, of the shape and size nearly of one hemisphere, in which it will be found broken in many pieces easily separable; and it will, besides, be somewhat bent, generally. The masonry behind will be much jarred, and, unless strongly bonded, be considerably displaced; moreover, unless the thickness of three feet is well tied into thicker masses immediately adjacent on the sides, and above and below, the general damage will be severe.

2nd.—This plate will be much the stronger for being in a single mass, and not made up of several thinner plates. The continuity, effected by bolts and rivets, of the made-up plates, is broken even by weak assaults, so that, afterward, the stronger, instead of a joint opposition, finds only a succession of feeble resistances.

3rd.—A thickness of two inches is ample for shutters designed to stop the largest grape shot. With this thickness, they will be neither perforated nor deformed by anything less than cannon balls or shells. These shutters also, for the reasons just given, should be made of a single thickness. The firings show the necessity of concealing entirely, even from the smallest iron missile, their hinges and fastenings.

4th.—A wrought-iron plate of half an inch in thickness is adequate to protect the outer margins, and the offsets of embrasures, from injury by grape or canister shot.

* This is probably scarcely sufficient, as large pieces were broken off a plate of wrought-iron 8 inches thick, by *wrought* iron 68-pdr. shot, at a range of 400 yards, during a series of experiments made at Woolwich by the Ordnance Select Committee, in consequence of a suggestion by General Sir John Burgoyne.—Ed.

187. The brittleness of cast-iron unfits it for use as a means of directly resisting the shock of cannon balls ;* this has long been well known. It was considered, however, worth while to try whether its cohesive strength might not be profited of, by diffusing the shock of a ball over a considerable surface of this material, through the intermedium of a thick plate of wrought-iron. The compound plate of wrought-iron interposed in the trials, was made up of eight half-inch plates, solidly riveted together, and a very even and uniform bearing of this 4-inch compound plate upon the cast-iron was secured—as perfect, certainly, as could be effected in general practice; nevertheless, the cast-iron block was always broken, splintered, or badly cracked, by a ball striking the wrought-iron plate in front of it.

This material may, of course, enter usefully into the construction of casemate embrasures, as dowels, ties, pintle-sockets, &c., but should not be relied on to resist the direct action of balls or shells.

SECTION II.

The Size and Form of Exterior Openings for Embrasures.

188. The great importance of keeping the area of the outside openings of casemate embrasures at a minimum will clearly appear from our experiments: 1st, the number of the enemy's missiles passing through the opening will, of course, increase with the enlargement of that area; and 2ndly, whatever may be the peculiar form of any embrasure, there must be a margin, larger as the opening is larger, where the walls, being materially weaker than elsewhere, will suffer the more from battering guns.

189. Although the first proposition seems not to need enunciation, and the second to be scarcely less self-evident, there appears to have been, with some foreign engineers, of the present day even, a very slight appreciation of the first especially. They have taken some heed of the second, by giving thickness to the wall around, and by making the cheeks, sill, and lintel, of large blocks of stone; but, by inordinately spreading the exterior opening, they have shown that they looked upon the first as of little moment. For instance, in a large casemated battery erected in Europe within the last fifteen years, for the defence of one of the great ports, casemate embrasures have been introduced having an exterior opening of 54 square feet, and allowing the gun a horizontal traverse of only 40°; while the embrasures of our second target, which allow all the elevation and depression necessary, and a lateral range of 60°, have an exterior opening of only $8\frac{3}{10}$ square feet.†

190. It is easy to demonstrate the very grave consequences involved in an unnecessary enlargement of this exterior opening.

Suppose a hundred-gun ship to be placed within good canister range of a casemated battery of about the ship's length and height; to the 50 guns of the ship's broadside there would be opposed about 24 guns in two tiers, in the battery. The ship would fire each gun once in three minutes, or, 10 times in half an hour; the 50 guns would therefore make 500 discharges within that time.

* Blocks of cast iron 30 inches thick were cracked quite through by 68-pdr. shot at a range of 400 yards, in the experiments at Woolwich above mentioned.—Ed.

† This has been partly caused by the necessity hitherto existing for protecting the pivot by a sufficient thickness of masonry in front, the weakness of which in these experimental embrasures is described in Par. 225; but it has been obviated by the introduction of the ribbed racers, and the consequent *omission of the pivot*, recommended by the Select Committee at Woolwich after many experiments, so that the neck of the embrasure may henceforward be placed close to the outer surface of the wall, and the exterior aperture may be made even smaller than those of the experimental embrasures.—Ed.

With 156* balls in each 32-pdr. canister (weighing in all 31½ lbs.), there would be thrown 78,000 balls in 30 minutes. Supposing one-half to miss the fort—which, considering the size of the object and the short distance, is a very large allowance—there would still remain the number of 39,000 balls to strike a surface of (say) 6,000 square feet—that is, on each square foot = 6½ balls.

Or, within the exterior opening of one of the embrasures of our 2nd target —of which the area is 8·9 square feet, there would fall . . . 58 balls, all not intercepted by the gun itself passing into the casemate among the men serving the guns.

Within the European embrasure above mentioned, having 54 square feet of opening, there would be received in half an hour . . . . . 351 balls.

191. Should this idea be carried still further, as it ought, and the ship's canisters be filled with musket balls—each 32-pdr. canister holding 639 balls—the number of balls to the square foot of surface of the battery would be 26

The number received in half an hour within the exterior opening of the smaller embrasure would be, therefore 231

And within the larger embrasure in the same time 1,404

192. Nor, would it be fully measuring the effect of this exposure to state that if the ship's guns were of the calibre of 8 inches—and there are even now many of larger calibre, and the tendency is to increase the calibre of both ship and shore-guns —supplied with canister holding 294 iron balls of 1·05 inch, or 1,243 musket balls, the number of the former discharged in half an hour against each square foot would not be less than 12

Upon the exterior area of the smaller embrasure, not less than . . . 106

And upon the large embrasure not less than 648

And the number of musket balls discharged in half an hour against each square foot, from an 8-inch gun, would be not less than 51

Upon the opening of the smaller embrasure not less than 453

And of the larger, not less than 2,754

193. In our experiments, the musket balls fired in canisters, from a distance of 200 yards, passed clean through the screens made of pine boards one inch thick, whether they hit directly, or by reflection.

194. In no instance did we notice any fusion of these balls into clusters—the marks made by them on the target, and on the screen, being clearly the effects of single bullets.

195. The effects of the small iron canister balls—diameter 1·05 inch, were considerable; when broken upon the cheeks of granite embrasures, the larger fragments passed through the screen; when the balls struck brick-work or cement concrete, they produced craters about three inches in diameter by about 1½ inch deep; when they struck near the edges of the embrasures, they broke off considerable pieces, even from the granite—they have, therefore, as well as the musket balls, all the force necessary for the particular object in such an attack—namely, killing and wounding the men serving the guns of the fort, and thereby silencing its fire.

196. This is the place to recall the fact that by way of showing one of the consequences of an unnecessary expansion of the outer opening of an embrasure, a line was drawn on the target around two sides of the margin of Embrasure No. 7, so as to represent, very nearly, with the other two sides, the exterior opening of an embrasure of the first-built of our casemated batteries (finished in 1810). The exterior opening

* In the experiments at Gavre, in France, in 1837, with grape and canister shot, the canon-obusier 30-pdr., and the long 30-pdr. (French), both fired canisters containing each 120 iron balls of 1·05 inch in diameter.

of Embrasure No. 7 was 3 ft. 4 in. by 2 ft. 8 in., equal to $8\frac{9}{10}$ square feet; of the embrasure represented, in the way just stated, it was 5 ft. by 4 ft.—equal to 20 square feet.

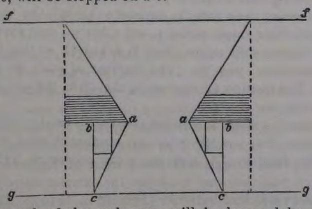
The space between these two openings, that is, the excess of the larger over the smaller, amounting to 11·1 square feet, was struck by 108 balls in the course of our firing with spherical case, canister, and grape shot—this embrasure not having been, more than any other, the particular aim of this kind of firing.

The whole number of small balls fired at the two targets during all our firings—counting spherical case filled with musket balls, canister shot of all sizes—including those filled with musket balls and grape shot, was 32,555; that is to say, a number a little less than would be fired in 51 discharges of musket ball canister from 32-pdrs., in other words, from a single "broadside" (plus one gun) from the ship, 639 by 51 = 32,589.

All these 108 balls, excluded by Embrasure No. 7, would of course have entered, had its opening conformed to the larger outline; but even this larger outline scarcely exceeded one third of the exposure of the European embrasure above mentioned; into which there would have passed, in the same time, according to the proportion, the number of 438 balls, over and above what passed into No. 7.

197. The trials, in firing from the target, proved that, if the embrasure were well built, the ball, in passing out from the gun, whether traversed, or elevated, or depressed to the extreme degree, might pass within about an inch of the outer edge of the embrasure, without injury by the blast of the gun to the material of the exterior margin. This may therefore be, with firm materials, a condition limiting the exterior opening. The minimum in the size of the throat is fixed by the space occupied by the muzzle of the gun, in its various positions; and as the area of the exterior opening will be the larger, as it is further from the throat, the latter should be placed as far to the front as the service of the gun and carriage will allow. The surfaces connecting the two areas, and which form the outer cheeks, sill, and lintel, have generally been flaring planes; to which one great objection is that they reflect inward all missiles which impinge thereon in lines parallel, or nearly so, to the directrix; so that, virtually, as regards their admission into the casemate, the throat has had, with that form of embrasure, the full capacity of the exterior opening. This is very strikingly shown by the great number of balls thus reflected in our firings.

198. If the outer portion of the embrasure be traced according to the bent line, *a b c*, instead of the straight line, *a c*, it is evident that balls that would otherwise be reflected from the surface, *a c*, will be stopped on *a b*.



199. But the strength of the embrasure will be lessened by the removal of the material lying within the space of which *a b c* is the horizontal section. This is, in fact, of little moment, because the strength lost by adopting the bent line *a b c* may

be much more than supplied by placing along *a b* a material more resisting than the masonry of which the flaring cheeks and throat-jambs have heretofore been made ; and this we shall see is required by other considerations.

200. It is plain that if the thickness *f g*, of the wall, is needed to resist the battering of heavy balls, no ball striking anywhere between the two lines, *f g*—*f g*, will be adequately resisted with the old form, *c a f*—*c a f*, of masonry embrasures. But by inserting a stronger material on each side of the throat, this deficiency of strength may be supplied, without filling up the space *a b c*, as it will need but a slight augmentation of the thickness of this stronger material to secure full compensation for the material thus omitted.

201. It is also evident that by building in enough of the stronger material on each side of the throat, and adopting this new form, *a b c*, for the outer portion of the embrasure, there will be a general gain of strength, since up to the very edge of the throat plates there may be as much strength as there is beyond the lines *f g*—*f g*. At the same time, by substituting for the reflecting surface *a c* the plane *a b*, all missiles, whether large or small, that do not pass the throat without touching, will be stopped, either upon the outside of the wall or upon the throat plate.

202. Our experiments show that wrought iron is the best material for insertion as above mentioned; and that a thickness of 8 inches of wrought-iron, solidly backed with masonry, will resist an 8-inch solid ball fired with $10\frac{1}{4}$ lbs. of powder from a distance of 200 yards.* It is necessary, as is also shown by the firings, that the plates of iron should have considerable breadth to prevent heavy balls from forcing themselves in between the inner edge and the masonry, thereby crowding the plate edgewise into the throat.

203. With a view to gaining strength, by burying more deeply the iron throat plates in the masonry of the embrasure, rectangular shoulders of masonry were made to project from the solid of the cheek, into the space *a b c*, as seen by the dotted lines in the above figure. They stopped balls nearly as well as the unbroken surface, *a b*; and they augmented somewhat the resistance of the cheeks. Being enclosed in a facing of boiler iron they were not injured by small balls—but they increased the number of fragments cast into the casemate by heavier balls, and they do not prove to be an essential part of an improved embrasure. The additional strength imparted by them may be better secured in other ways. Embrasures Nos. 3, 7, 8, and 9, were thus constructed.

204. It is well to report in this place a summary of the exact effects under our trials of the broken, or offseted cheeks, as compared with the flaring ones: 1st, in stopping balls, and 2nd, in glancing them into the casemate through the throat.

The number of balls from grape, canister, and spherical case shot, that were reflected from the cheeks of flaring embrasures (Nos. 1, 2, and 4), so that they passed through the throat into the casemate, was 40. The number of such shots stopped by these embrasures was 2. The fraction $\frac{40}{42}$ represents, therefore, the proportion reflected, and $\frac{2}{42}$ the proportion arrested.

In the embrasures with broken or offseted cheeks, the total number reflected through from the cheeks, offsets, &c., was 19—while the number stopped by them was 326—so that in this case, the fraction $\frac{19}{345}$ represents the proportion reflected, and $\frac{326}{345}$ the proportion stopped.

Or, these proportions may be represented thus:—

Embrasure with flaring cheeks.	5 per ct. stopped.
	95 per ct. reflected.
Embrasure with offseted cheeks.	94 per ct. stopped.
	6 per ct. reflected.

* See Note page 22.—Ed.

As it was important to settle beyond question the effect, in arresting small missiles, of the offseted cheeks substituted for flaring ones, the firing of small balls was chiefly directed at the former; and hence the greater number of these balls that were received on the cheeks of that form.

205. It results from the facts and statements adduced thus far, that if, instead of giving to embrasures flaring cheeks, the exterior cheeks be notched in, so to speak, at right angles, or nearly so, to the plane of the throat; or, to repeat words often before used, be offseted, only those missiles that arrive directly within the area of the throat, will enter at all, excepting, indeed, a very small proportion that may be glanced in from the very edges of the outer opening.

206. In estimating the number that will pass directly through this throat opening, from the 100-gun ship, in half an hour—we must take the clear area of this throat of the target embrasures—which was 1 foot 6 inches wide, by 2 feet 7 inches high, giving $3\frac{9}{10}$ square feet.

The comparative numbers would be, therefore, as follows:

32-pdr. gun, firing iron balls of 1·05 inch in diameter—		
Through the throat of target embrasure	25	balls.
Within exterior opening of target embrasure	58	"
Within exterior opening of European embrasure . . .	351	"
8-inch gun, firing iron balls of 1·05 inch in diameter—		
Through the throat of target embrasure	46	"
Within exterior opening of target embrasure	106	"
Within exterior opening of European embrasure . . .	648	"
32-pdr. gun, firing canisters filled with musket balls—		
Through the throat of target embrasure	101	"
Within exterior opening of target embrasure	231	"
Within exterior opening of European embrasure . . .	1,404	"
8-inch gun, firing canisters filled with musket balls—		
Through the throat of target embrasure.	198	"
Within exterior opening of target embrasure.	553	"
Within exterior opening of European embrasure. . . .	2,754	"

SECTION III.

EMBRASURE SHUTTERS.

207. We see, from the comparison just made, that, notwithstanding the very great advantage derived, first, from reducing the size of the exterior opening, and next, from changing the form of the portion of the embrasure exterior to the throat—the exposure of the men serving, even with the target embrasure, a casemate gun will still be great. They will be exposed during every half hour of action to 25—to 46—to 101, or to 198 balls, according to the various suppositions we have made, as to kind of gun and missile. From 1 to 6 balls entering the embrasure every minute, directly upon the place where the gunners are clustered, must make the service a very dangerous one—if indeed it could be continued with any effect in such peril.

208. These, and such like considerations, led to the trial in the target of *embrasure-shutters;* and the experiments with these have shown that a thickness of 2 inches of wrought-iron will certainly repel all such balls, as grape and canister.

209. A grape shot of $4\frac{1}{2}$ lbs. fired from an 8-inch Columbiad, at the distance of 200 yards, produced no deforming or otherwise injurious effect upon a wrought-iron shutter of $1\frac{1}{2}$ inch in thickness, composed of three half-inch sheets. By simple arrangements, the centres of motion and the fastening bolts can be screened from these small balls.

210. The shutter will be closed from the moment of firing until the gun is loaded—is again in battery, and ready to be again discharged; so that it will be for instants of time, only, that the gunners will be at all in danger from the enemy's small shots.

211. It cannot yet be asserted positively that the shutters will close spontaneously at each discharge of the gun, because trial has not been made with shutters improved by the results of our latest experiments. But the tendency to close was so manifest, and so invariably exhibited, as to leave no doubt that a simpler mounting, and more accurate centering, would insure it.

212. This result is very desirable on account, not only of the quickness of this spontaneous action, as respects cover for the gunners, but because of the consequent exclusion of smoke. The same reaction of the air will drive back the shutter, that forces back into the casemate sometimes a large part of the smoke of the discharge.

213. In our firings from the embrasures, the shutters were, each time before the discharge, opened out by hand, and placed snugly against the cheeks; this might answer were they perfectly hung; but it is to be regretted that it did not occur to any one to leave them a short distance from the cheeks, in order that the outward blast of the gun, driving them forcibly against the cheeks, might cause a stronger reaction. A stiff spring upon the back of the shutter, keeping it, until forced, at a short distance from the cheek, will insure, it is believed, the requisite recoil; but with good centering this will hardly be necessary.

SECTION IV.

THROAT OF EMBRASURE.

214. It was obviously a matter to be inquired into, whether or not, the throat itself could be reduced in width with safety.

To this end, some instructive trials were made (as before said) at my request, under the direction of Major J. G. Brainard, of the Corps of Engineers, then Superintendent of the Military Academy.

215. It was desired to learn something as to what may be called the cone of blast—which might have, perhaps, very near the mouth of the gun at any rate, limits pretty well defined, up to which we might safely bring the edges of our throat plates.

216. These experiments are given in the preceding pages in full detail; and offer an interesting study.

217. The principal results for our object are, that this cone diverges quickly from the mouth of the gun; that the action within its limits is very violent; that only very solid and firmly imbedded substances can be placed within the limits, or on their verge, near the mouth of the gun, since even the iron plates of a compound throat plate were there torn asunder by the blast—but that, undoubtedly, while a solid 8-inch plate firmly imbedded in masonry may be relied on at the same distance from the muzzle, and from the prolonged cylinder of the bore, that was found to test so severely the compound plates submitted to the trial—any less solid and firm material must be further removed. Of course, the nearer the edge of the throat plate is to the face of the muzzle, the nearer it may be to the prolonged cylinder. *

SECTION V.

THICKNESS OF SCARP.

218. The internal arrangement of the casemate, with reference to the handling of the gun, and especially the traversing it for horizontal scope; the place chosen for the axis of this horizontal motion; and the form and dimensions of the gun and carriage, including chassis, impose conditions affecting the thickness of the wall at, and immediately around, the embrasure, and affecting also the form of the latter.

* The centre on which the 8-inch Columbiad traversed appears to have been in line with the rear faces of the wrought iron throat plates, and it traversed 60°.—Ed.

219. A thickness there of five feet has been assumed in our constructions, and satisfies all these conditions well. But it has been a question of interest, increasing with the growing calibres of naval armaments, whether this thickness is now sufficient. And it was in consequence thereof that some very severe firing was directed against our 2nd target. The gun was a 10-inch Columbiad, placed within 114 yards, firing solid balls, weighing 128 lbs., with a charge of 18 lbs. of powder.

220. The general conclusion from these trials is that, whether of cement concrete, of bricks, or of hard stones, the portion of the wall at, and around each embrasure, having the thickness of five feet only, should be no larger than is indispensable for the adaptation of the gun and carriage to the embrasure; if restricted to a small area, this thickness will suffice, not otherwise.

221. The thickness of five feet will resist a number of these balls, impinging in succession, on that space, provided the bond expand promptly, above, below, and on each side, into a thickness greater by some $2\frac{1}{2}$ ft., or 3 ft., or more. Were the wall no thicker, generally, than five feet, being reinforced only by piers some 15 feet apart, it would soon be seriously damaged by battering at short distances with such calibres.

222. Wrought-iron throat plates of eight inches thickness, placed in the embrasure, and backed by three feet of solid masonry, will be equivalent, at least, to the five feet of masonry on either side; and, but for the great cost, this construction might be extended as far above, below, and on either hand, as is necessary for the full and free use of the gun. The great additional expense would not, however, be compensated by any advantage of moment. In that case, the throat opening would be also the exterior opening of the embrasure, because the throat would lie in the outer surface of the wall. This opening being in area but 3·90 feet, would be a very great reduction in size, certainly, from that of the European embrasure (of 54 square feet) so often mentioned, and it would be less, by five square feet, than the outside opening of the 2nd target embrasures; but it would be no better than these last, in reference to the exclusion of an enemy's missiles, since, as we have seen, the offseted embrasure restricts the passage way to the area of the throat.

223. Were it not for the vastly greater cost, the whole scarp might be faced with iron—indeed might be made of iron only; but, until there shall be much stronger reasons than now exist, or are now anticipated, for believing that well constructed masonry-batteries may be breached by naval broadsides, the cheaper construction may be safely followed—especially as, should such a necessity ever arise, they may be externally plated with iron.

224. To repeat: the scarp at the embrasure may be safely made of the thickness of 5 feet, provided the thickness immediately above, below, and on the sides, be increased considerably. The space required to be of about this thickness, to accommodate advantageously the gun and carriage, is so small that it may be said to be part of the thicker surrounding mass, by which it really is supported in its resistance.

225. A detail of interest presented itself in the course of the firing, in relation to the thickness of the scarp near the embrasure. It was this: a 24-pdr. ball, hitting the wall immediately in front of a recess made to receive the "tongue" of the chassis—which recess extended to within two feet of the outside of the wall—perforated this two feet, and, being less in diameter than the height of the "tongue hole," passed entirely through, without touching anywhere else. Had there been a carriage there, with its "pintle" in place, the latter would probably have been broken, and the carriage rendered for the time unserviceable. That "tongue hole" was seven inches high, it need be only about half as high, and there should be a thick plate of wrought-iron buried in the wall, directly in front of the pintle, to stop such balls or larger ones.

SECTION VI.

EFFECTS OF FIRING FROM CASEMATES UPON SHIPS.

226. The firings from, and at, our embrasure targets, have given us, as we have seen, some instructive facts as to the necessity, in reference to the free use and efficient service of casemated batteries, of certain precautionary measures. Do not these results teach us also something in the opposite direction—something as to the offensive power of these batteries, not hitherto perhaps fully considered - especially in reference to the effects of small missiles upon ships? For instance: On our hypothesis, the casemated battery of about equal external surface with the 100-gun ship—that is, of about 6,000 square feet, would contain about 24 guns. Supposing these to be 32-pdrs. firing canisters containing 156 balls of 1″·05 each; and, as before, each gun firing 10 times in half an hour—allowing half the balls to miss the ship—there would be three balls received by each square foot, and as the port-holes are stated to be three feet high by three and a half feet (equal 10′·5 square feet), there would pass into each port 31 balls, and into the 50 ports 1,550 balls, within the half hour.

If the canisters were filled with musket balls, there would be 126 thrown into each port, and 6,300 into the 50 ports.

The guns being of 8-inch calibre, which is the common calibre of our important batteries, the number of 1″·05 balls to each port would be 52; and to the 50 ports, 2,600.

And, were the same guns to fire musket balls, in their canisters, there would be thrown into each port, 252 balls; and into the 50 ports, 12,600 balls in the half hour.

227. The following table gives, in a compact form, a synopsis of the principal effects of the firing of small canister shots into embrasures of several sizes; and also into the ports of ships, on our supposition of a 100-gun ship, in opposition for half an hour, at close quarters, to a 24-gun battery:—

TABLE NO. 19.

Giving the number of small iron and leaden canister balls, discharged in half an hour through the embrasures of a casemated battery, of 24 guns, and through the port-holes of a ship in opposition, having 50 guns in each broadside, the total surface of fort and ship being each about 6,000 square feet, and specifying, in the cases of 32-pdr. and 8-inch gun, the numbers entering each embrasure and each port-hole.

	No. entering each embrasure.		No. entering all the embrasures.		No. entering each port.		No. entering all the ports.	
	Musket balls.	Iron balls of 1″·05.	Musket balls.	Iron balls of 1″·05.	Musket balls.	Iron balls of 1″·05.	Musket balls.	Iron balls of 1″·05.
FROM 32 PDR.								
Large embrasure of 54 square feet	1,404	351	33,696	8,424				
Target embrasure with flaring cheeks ...	231	58	5,544	1,392				
Target embrasure with offseted cheeks ...	101	25	2,424	600				
Target embrasures with shutters*	10	3	240	72				
Ship's port-holes					126	31	6,300	1,550
FROM 8-INCH GUNS.								
Large embrasures of 54 square feet	2,754	648	66,096	15,552				
Target embrasures with flaring cheeks...	453	106	10,872	2,544				
Target embrasures with offseted cheeks	198	46	4,752	1,104				
Target embrasure with shutters*	20	5	480	120				
Ship's port-holes					252	52	12,600	2,600

* Supposing that for the instants the shutters are open, one-tenth of the number falling within the area of the throat may enter the casemate.

228. On an examination of the preceding table, we are surprised at the great numbers of these small, but fatal, missiles to which the gunners of the battery would be exposed, even with our comparatively very small target-embrasure. We see plainly the necessity of reducing that number, by removing the flaring outside cheeks; and, also, the vast advantage that the shutters afford of nullifying, nearly, the effects of this kind of fire.

229. Indeed it is difficult to understand how a casemated battery, having large embrasures, can be served at all, after a ship has gained a position, within a short distance, and opened her fire of small canister balls. For the ship to fire grape, or *larger* canister balls, would be to abuse her opportunity, since these larger balls would be no better, in any such conflict, than the smaller ones, while they would be far less numerous. Musket balls, used as canister shot, would have all the force necessary; and we see, by the table, that there would be thrown of these, in half an hour, into the casemate, through 24 embrasures, of 54 square feet of area each, by fifty 32-pdrs., no fewer than 33,696—being 1,404 through each embrasure.

230. Were the battery to retort upon the ship with the same missiles, the advantage would still be greatly with the ship, because against the 1,404 balls received by each embrasure, there would be thrown but 126 into each port; and into the 50 ports, there would be returned but 6,300 shots, against the above number of 33,696, poured into the 24 embrasures.

231. On the reduction of the exposed opening of the embrasure, however, the proportion becomes less and less unfavourable to the battery—turning, before long, very decidedly in its favour. When the size is reduced to that of the 2nd target embrasures, the ship will receive in her 50 ports 6,300, as before, against 5,544 entering the 24 embrasures of the battery. When the offseted cheeks are introduced, the 6,300 will stand against 2,424; and when the shutters also, the 6,300 are to be compared with 240 only.

232. It may, therefore, become so much to the advantage of the battery to resort to these missiles, especially with 8-inch guns, that the ship will be obliged either to give up the idea of close quarters, or provide herself with quickly-moving port-shutters.

233. In corroboration of the preceding calculations, showing that they are not exaggerations, it is here stated as one of the recorded results of our firings, that the total number of small missiles that passed through the throats of our nine target embrasures without touching—the area of the throat being 3′·9—was 234. And, as before said, the whole of our firing at the target, with small balls, was equivalent to only a single broadside from the 50 guns of the ship.

SECTION VII.

CONTESTS OF SHIPS WITH EACH OTHER.

234. Although it is not in the particular direction of our enquiries, we cannot help thinking, in this connection, that possibly our results and calculations may have some bearing in certain cases, upon naval actions, ship against ship.

235. We are told in naval histories of ships of war lying engaged "*yard-arm and yard-arm*" for hours, and yet they report losses incredibly small, considering the time and the proximity; the ships, moreover, are seldom sunk, or otherwise destroyed, except by taking fire, and, though badly crippled, no doubt, make long voyages with no other than impromptu repairs.

236. Without venturing to pry into this curious result, we may say that if the want of more decided effects is the consequence of the want of more accurate aim in the

solid balls (fired with some admixture probably of grape shot), this reason would apply, in a much slighter degree, to canister shot at short ranges, since it would suffice if the gun were merely pointed *towards* the enemy's hull, for part of the cone of balls to fall upon her sides.

237. Is it not difficult to conceive how a ship's crew could survive one hour's firing, when there would be poured into her 50 ports more than 25,000 musket balls—into each port, more than 500 such balls?

238. Perhaps the suggestion may be pardoned, that in these close conflicts, a charge of powder, very much reduced, in order not to endanger the gun, might be fired with a shell, and, in addition, a canister of musket balls. The latter would have all the force requisite to penetrate human flesh; and the shell would certainly have, at a distance so short, power to penetrate into the enemy's side far enough to cause great damage by explosion.

SECTION VIII.

HISTORY OF EMBRASURE THAT HAS BEEN INTRODUCED IN THE COAST BATTERIES OF THE UNITED STATES.

239. It seems appropriate to this narrative of our recent trials of casemate embrasures to refer briefly to the history of the embrasure that has been introduced in the coast batteries of the United States.

240. The first casemated battery was completed in 1808. It has two tiers of guns in casemates, and one in barbette. The exterior openings of the lower embrasures are 4′ 8″ by 6 feet, giving an area of 28 square feet; and of the 2nd tier, 3′ 8″ by 5 feet—area $18\frac{1}{3}$ square feet—the horizontal traverse of the guns being limited to 44 degrees.

241. Within three or four years of the time just mentioned, two other casemated batteries were built, each having a single tier of guns in casemates, with exterior openings of 4 ft. 5 in. by 5 feet, area 22 square feet, and with horizontal scope, one of about 42 degrees, and the other of about 45 degrees.

242. In 1815, the author of this report was called on to prepare a project for the defence of an important channel; and having been convinced, while employed as an assistant in the construction of two of the batteries just mentioned, that the principles and the details by which the embrasures and the dependent casemates had thus far been regulated, were erroneous and defective, set about a careful study of the conditions to be fulfilled in providing for the heavy guns of that period, mounted on a casemate carriage that had already been proved and adopted. The result was an embrasure having an exterior opening of 4 feet wide by 2 ft. 6 in. high at the outside line of the cheeks, and 3 feet high at the key of the covering arch, the throat being 1 ft. 10 in. wide. This provided for all the depression and elevation of the gun that the carriage permitted, and also for a horizontal scope of full 60 degrees. Covered with a lintel, instead of an arch, the height of the exterior opening might be a little less than 3 feet.

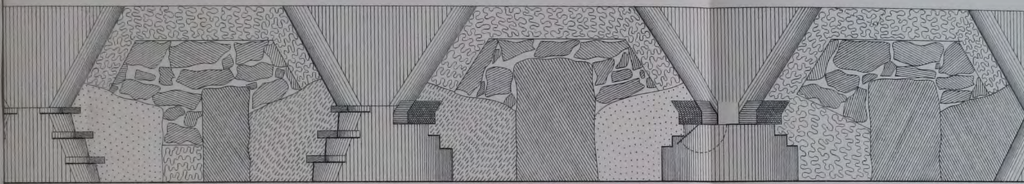
243. The plan of this embrasure shows that the interior opening is 5 ft. 6 in. wide, and that the plane of the throat is within 2 feet of the outside of the wall, which, just at the embrasure, is 5 feet thick.

244. A slight modification fitted this embrasure, when applied to flanking or interior defence, to receive at first a carronade of large calibre, and of late years, a howitzer instead. When these latter were liable to be assailed by musketry the outer cheeks were made *en cremaillère* (notched), a long-known device.

1st TARGET.

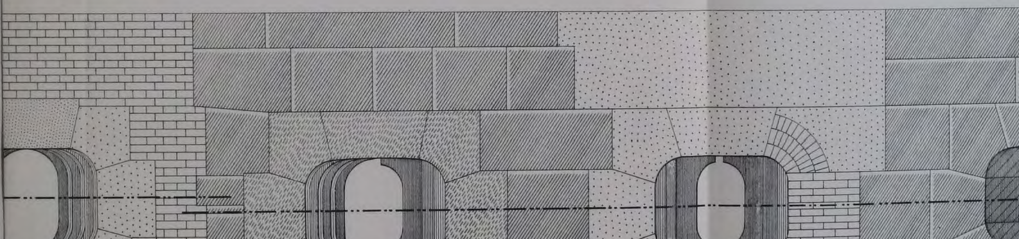
Fig. 1.

Plan on c. d.

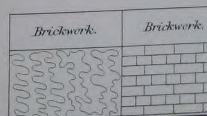


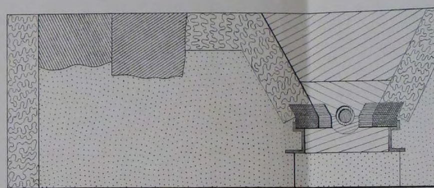
N°. 5. N°. 4. N°. 3.

Fig. 2.

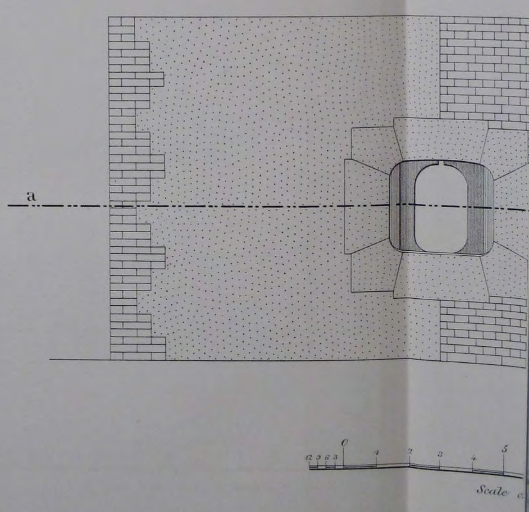


Exterior Elevation.





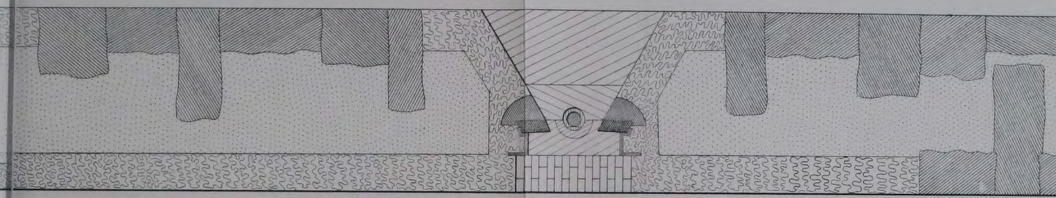
Nº 9.



2nd TARGET.

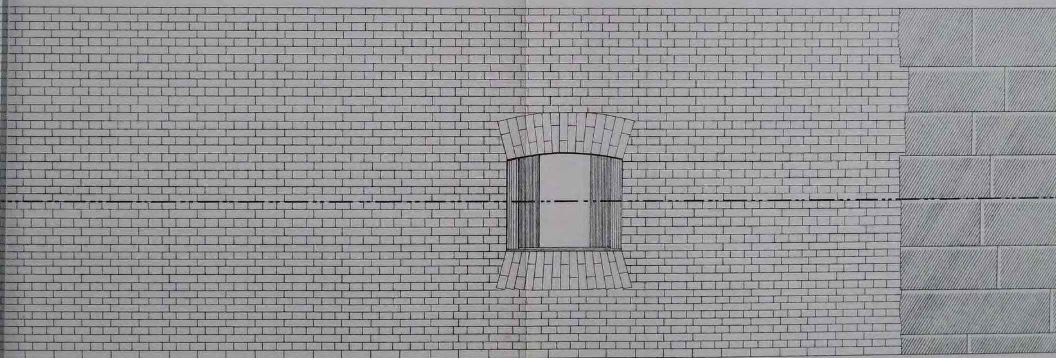
Fig. 3.

Plan on a. b.



No. 8.

Fig. 4.



Exterior Elevation.

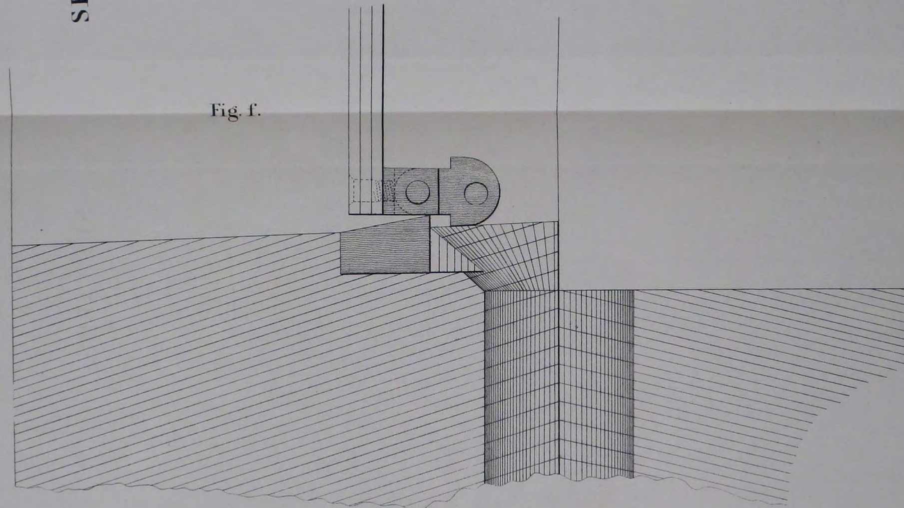
...ch to Four Feet.

See Ref...

SHUTT

Section on E. F.

Fig. f.



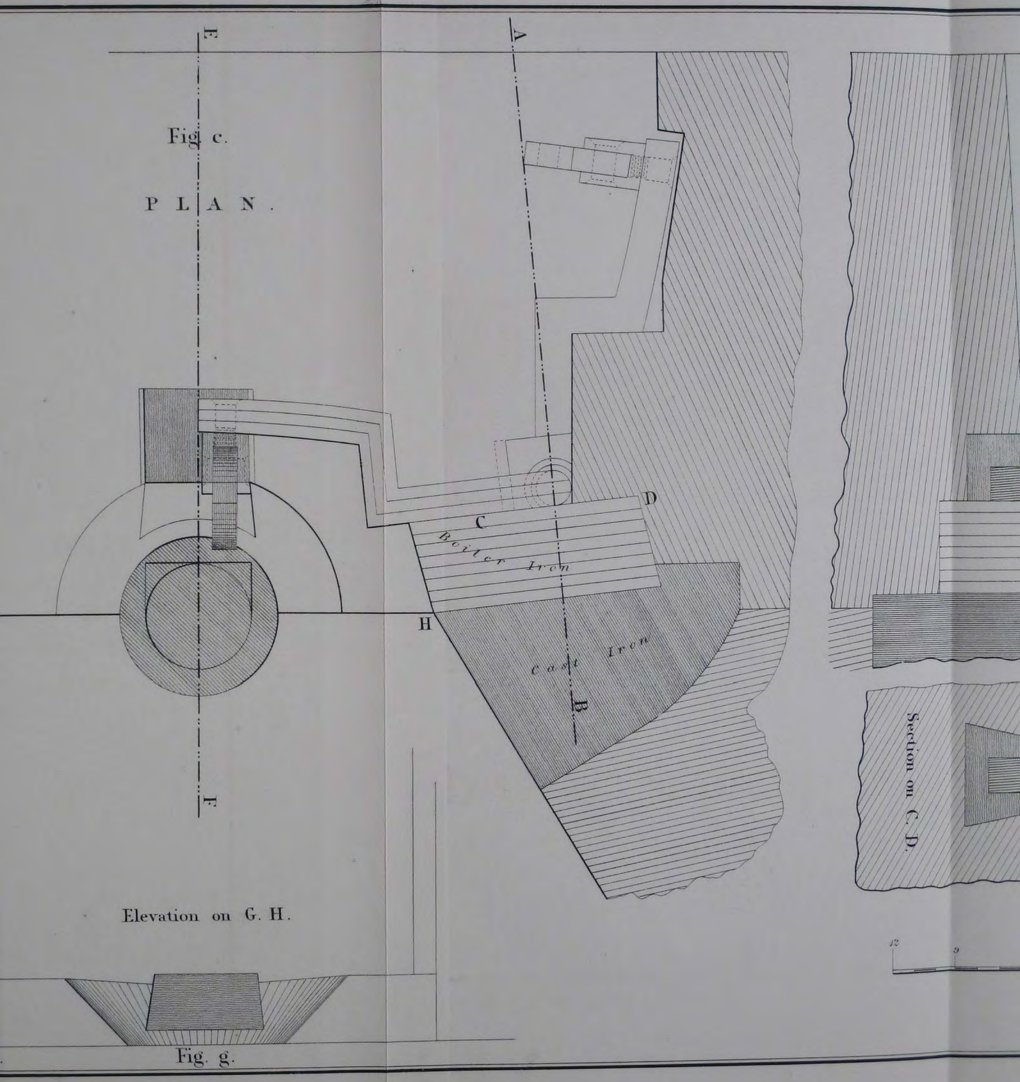


Fig. c.
PLAN.
E
F
A
B
C
D
H
Boiler Iron
Cast Iron
Section on C. D.
Elevation on G. H.
Fig. g.
12
9

245. It was with timidity and hesitation that the cheeks and throat of this embrasure were placed so near the track of the ball, when fired from the casemate, with the maximum obliquity, and the results of an early trial with experimental embrasures at Fort Monroe gave some sanction to the doubt. The first two under trial were built up with lime mortar, and were soon shaken to pieces by the blast of the gun. Another one, however, constructed of bricks laid in cement-mortar, sustained without injury several hundred discharges.*

246. These last results have been confirmed wherever there has been practice from our embrasures, which, with immaterial differences, have since 1815 been constructed in all our casemated batteries according to the preceding description.

247. This being the state of things with these embrasures of 1815, an increase in their strength had, within a brief period, become expedient, not to say necessary, by the augmented calibres in ships' armaments.

248. It was considered that this strength might be given, perhaps, in part, by reducing the opening, and in part by incorporating a stronger material in the portion where the quantity of masonry was unavoidably small, from the shape of the embrasure.

349. The resistance afforded by the existing embrasure to the blast of its own gun justified the expectation that the exterior opening might be reduced nearly to an absolute minimum, and the facility with which large masses of iron are now wrought suggested that, by its use to a limited extent, not only might a greatly augmented strength be secured against the effects of a large ball, but small ones might be excluded altogether.

250. Our target embrasures were successively devised, further and further to test these ideas. The trials sustained by them have become a part of the history of the American embrasure. And if there be any force in the deductions drawn in the preceding pages from these trials, the improvements they suggest as to the materials, dimensions, form, and details, are of importance.

251. The embrasure applied, since these experiments, to our casemated batteries, and which may be called the embrasure of 1855, devised in accordance with these deductions, and of which a model received your approval, is believed to satisfy completely all important conditions.

252. The greatly augmented strength and efficiency thus imparted to our system of national defence will be due to the enlightened and liberal forecast which prompted you, as Secretary of War, to sanction and sustain the course of experiments of which this report is the record.

Respectfully submitted.

JOS. G. TOTTEN,

Brevet Brigadier General and Chief Engineer.

TO THE HON. JEFFERSON DAVIS,

Secretary of War.

* Lieutenant Mansfield, then of the Engineers, now Inspector General of the Army, in a letter dated early in 1830, at Fort Monroe, says: "1st. On my arrival at this place, in 1828, there was then standing an experiment embr sure, built wholly of cut free-stone, and of the same size as those here constructed—except that the cap was one stone instead of an arch. Soon after the firing through this embrasure commenced it fell to pieces, by the mortar leaving the joints, outside of the plane of the throat, and the stones separating and falling to the ground.

"2nd. Another embrasure was constructed (of bricks) in the same place, and of the same size, except as to the cap, which in this case was an arch of bricks only, laid in a mixture of equal parts of mortar and humid cement. This embrasure fell to pieces by the same means and in the same way.

"3rd. A third embrasure was constructed of bricks, like the second—being laid in cement. This has stood a trial of 270 discharges, and remains uninjured.

"4th. In each case there was about the same time allowed for the mortar and cement to set."

The same officer, writing in August, 1830, says: "The same embrasure" (the 3rd, above) "has "had many severe trials again this spring, with a 32-pdr., and it has not been in the least injured by the discharges."

PAPER II.

NOTES ON THE DEFENSIVE WORKS ROUND KERTCH, IN THE CRIMEA, CONSTRUCTED UNDER THE DIRECTIONS OF MAJOR STOKES, ROYAL ENGINEERS, BY THE ANGLO-TURKISH CONTINGENT, IN THE WINTER OF 1855-6.

COMPILED BY LIEUT. MAQUAY, R.E.

The object which the compiler of these notes has in view is to describe the nature, extent, position, and armament of the defensive works constructed at Kertch, and to touch upon the duties which devolved upon the Engineer Corps of the Turkish Contingent, during the occupation of the eastern peninsula of the Crimea by that force.

Early in October 1855, the Turkish Contingent, which had been encamped on the Bosphorus for some months, and whose destination had been repeatedly changed, commenced their disembarkation at Ak-burnu, or Fort Paul, and Yeni-kaleh, the former being a cape 3¼ miles south, the latter a fishing village 8 miles east of Kertch, posts which had been formed by strong lines thrown up by the force under Sir George Brown, immediately after their first occupation by the allies in June 1855. As the posts of Yeni-kaleh and Fort Paul were insufficiently supplied with water, and as they could not afford shelter to the stores and materiel of the Contingent, General Vivian decided upon fixing his head-quarters at Kertch, where he concentrated the bulk of his force, and formed his main depôts in November, 1855.

Kertch being an unfortified town of considerable extent, and exposed to attack from a large force of the enemy in the neighbourhood of Kaffa, General Vivian called upon Major Stokes, R.E., the chief engineer of his force, to plan works for the defence of the valuable depôt formed in the town, and to give security to the cantonments in which the troops were to pass the winter.

The town of Kertch (the Panticapœum of the ancients), is situated at the head of a bay of the same name, on the slopes and under the cliffs of a range of hills which abut abruptly on the bay at their eastern extremity, and thence run westerly about 15 miles into the country. On either side of this range lie two wide and extensive valleys. The northern one is very low and marshy near the town, and in the southern one, separated from the bay by a narrow causeway leading to Fort Paul, is a salt lake, forming a natural protection on this side. The town, before the war, contained 10,000 inhabitants, principally Germans and other colonists, and was an important depôt and naval station. It is built of a soft limestone, found in abundance in the neighbourhood; most of the houses are of one story, with well tiled roofs and comfortable interiors; but there are also some public buildings and private residences of considerable size and handsome construction. The two Greek churches and the Roman Catholic chapel were substantially built, and roofed with zinc. A large market place in the centre of the town; streets broad and well paved; houses, though regularly built, tinted with various bright colors;—all combined to give the town a pleasing and striking aspect when seen from a distance.

At the entry of the Contingent, however, the pleasing expectations excited at a distance gave way to disappointment and regret, for great numbers of the houses were found to be in ruins—bare walls, stripped of their roofs for firewood, or, still worse, destroyed in wanton mischief, met the eye at every turn. The greater part of the principal buildings, including Government stores, theatre, &c., had been totally destroyed, and the celebrated museum gutted. Many of the houses in the town, however, though deserted, were available for barracks and stores, and the Engineers were soon busied in converting to such purposes many of those that were injured.

In considering the defensive works which Major Stokes executed at Kertch, it is necessary to bear in mind the special object which those works were intended to attain, the isolation of the position, the peculiar circumstances of the Force, and the nature of the enemy with which it had to contend. These four considerations may be briefly stated as follows:—

1. The special object of the works was to give security to the large and valuable depôts of all kinds of stores which had been accumulated for an active campaign in the field, and to cover the winter cantonments of the force.

2. The isolation of its position during the winter rendered it especially necessary that no accident should befall the stores, which, once destroyed by an enemy's light cavalry, could not be replaced during the winter, the bay and straits of Kertch being liable to be frozen (an apprehension justified by the actual event); and for the same reason it was most desirable that the force thus cut off from communications or reinforcements, should sustain no reverse.

3. This latter consideration was the more influential from the peculiar circumstances of the force. The Contingent was so recently organized, that the officers did not speak the language of their men; and many of the regiments composing it were handed over by the Turks even after the works were commenced, and had then to learn the English system. It was therefore highly important that, in the event of an attack by the Russians, (which attack was threatened throughout the winter months), the Contingent should be victorious. This result would be most likely of attainment if, in their first action, the Turks had a rampart between them and an enemy—with sufficient room for manœuvring, so as to receive support.

4. The nature of the enemy, the active Cossack, rendered it peremptorily necessary that the town should be entirely closed, to prevent the possibility of the mischief and confusion that would ensue if a few squadrons of light troops should penetrate into the midst of the town, and set fire to the stores—a feat by no means difficult of accomplishment in the long and dark winter nights, by an enemy knowing the country, and who could easily secure his retreat in the face of a force so destitute of cavalry as was the Contingent.

These principal reasons influenced the Commanding Engineer to reject a system of detached works, and to intrench the whole position. The extent of the position it was not in his power to curtail. The range of hills, of which the most elevated, (marked on the plan as Vivian's Hill,) commanded the town, must necessarily be occupied. The cantonments were to be within the lines, and if placed on the ledge immediately below the crests of the hills, there would have been no water, and the troops would have been exposed, at that height, to even greater rigours than they suffered from the climate at the lower elevation adopted.

It has been objected that the lines were too extensive, but in point of fact their extent was rather apparent than real. Vivian's Hill—the key of the whole position—could not be abandoned to an enemy, and its occupation would moreover oblige him either to divide his forces, or to concentrate his attack on a confined front. An enemy advancing upon Kertch must approach by the roads leading from Arabat. It will be seen by the plan that the front bearing upon this approach was the least extensive, and the most carefully fortified. The attacking General would have four plans to choose from:—

1. He might attack the west front and master the key of the position.
2. He might station a strong force to make a feigned attack on the west front, and throw himself on the weak lines around the town, on the north, or Yeni-kaleh side.
3. He might advance by both the north and south valleys; or
4. He might throw himself entirely on the south side.

1. The first would lead him to occupy the broken ground in front of the west front, and against his attack in that direction it will be seen that the fortifications were principally constructed.

2. The second mode of attack would have enabled the English General to concentrate his whole force for the defence of the front menaced, leaving the care of the other fronts to their ordinary guards.

3. To execute the third plan the Russians must have been in very superior numbers, to allow of a division of forces, which would be entirely isolated, the one part from the other, by the Vivian range; that on the south having moreover to attack a position strong in itself and rendered very difficult of access by steep scarps and deep ditches.

4. The latter obstacles would deter him from staking his success on an attempt on this side.

From what has been said then, it appears that the actual defence was likely to be required only on a limited portion of the lines, and the formation of the ground facilitated the massing of the reserves in such a manner as to enable the General to bring them to bear in a very short time on any point menaced. Again, it must be borne in mind that these lines were not intended to resist a regular siege, but to enable a small force to maintain its position against superior numbers, until relieved.

To render its defence more certain, the Chief Engineer demanded that it should be armed by at least fifty heavy guns; the actual armament however fell far short of this number.

With these general observations we may pass to a more detailed description of the position.

The general trace of this continued line of works resembled an irregular hornwork having the bay for its base; the proper front faced the west or interior of the country, and while one flank rested on the crest of the hills, the other lay in the northern valley.

To facilitate a description of these works they may be generally grouped as follows:

1. The western front.
2. The southern front.
3. The northern front (which included the defences immediately about the town).
4. The interior defences.

Western Front.

The western front was 2,640 yards from the bay, and 1,400 yards beyond the Griffin Gates, at the extremity of the town; it was 770 yards long from one extremity to the other, measured in a straight line. This front was defended by five batteries, as follows:

1. Advanced	Battery of	3 guns	with 1	magazine.
2. Lyon's	"	1 gun.		
3. Mortar	"	4 mortars	2	"
4. Evans's	"	2 howitzers	1	"
5. Mosque	"	3 guns	2	"

Its trace was irregular, following the form of the ground, which was taken advantage of to give a searching musketry fire into the hollows by which the glacis was broken. The left rested on Vivian's Hill, already mentioned as the key of the position, and the line descended into the valley until the right rested on an open space commanding the low grounds where the Mosque Battery was built.

In front of and somewhat lower than Vivian's Hill, was a detached peak, whence a good flanking fire could be obtained for the whole front, and a commanding fire was obtained against any batteries that might be established at the sole point on the Arabat Road, where guns for the annoyance of this front could play upon the works without throwing up breastworks. This peak therefore offered great advantages as a position for a battery, but, being of a conical form, it was necessary to blast away the apex to obtain a terreplein. As it consisted of huge boulders of porous limestone full of rifts and shakes, this proved a tedious operation, but the persevering efforts of the miners at length obtained a sufficient space, the front faces of the battery, measured on the interior crest, being 24 and 36 feet long. It was an almost enclosed work substantially revetted with turf, both internally and externally, the parapet being 18 feet thick and 7 ft. 6 in. high, above the terreplein; the earth and turf for its construction had to be carried in sacks and sand bags, from the dip between it and Vivian's Hill to a considerable elevation, on the backs of the Turkish working parties. The Turk has a strong aversion to the use of the wheelbarrow, perhaps because it appears to assimilate him to a beast of draught; but to carry any burden he is as willing as he is sturdy and able.

Below the parapet of the battery was a trench and parapet for musketry, the whole being surrounded by a pointed ditch 15 feet wide and deep, the greater part of which was blasted out of solid rock. This battery mounted 3 guns, and had one barbette and 4 embrasures, two of the latter being spare ones. On the barbette was a British 24-pdr. mounted on a siege carriage; the platform however was peculiar in its construction: it consisted of stout oak planks spiked down to sleepers converging to the rear. The front of the platform was laid level, with a steeper rise to the rear than is generally given to a platform. The gun could thus fire in any direction over the curve of a semicircle, and yet always have its trunnions perfectly horizontal, a point not to be attained and causing inaccurate fire with the common platform; the recoil of the gun was nevertheless left quite free enough to ensure that no damage could accrue to the carriage. The two other guns were 9 oke* guns (corresponding to English 24-pdrs.) and could be worked in any two of the four embrasures, of which one commanded the ground in the front of the battery, two flanked the works along the western front, and the other flanked the ditches and scarps of the southern front. The four platforms for these guns were all of oak and of the usual dimensions.

The magazine was cut out of rock, and was of the usual form of rectangular field magazines; it was capable of containing two hundred rounds per gun.

Lyons's Battery was an auxiliary flank defence of one gun (11 oke) for this front; it fired through a narrow sally-port, which had a light drawbridge by which the advanced pickets could retire, the main sally-port of this front being rather distant.

The Mortar Battery of four 8-inch mortars was situated behind two large tumuli whence the mortars could shell any point of the ground in front; they were laid on stout oak platforms: one traverse and two large magazines in rear—one of which served as a laboratory—completed this battery. A covered road connected it with the principal magazine at the Museum.

Evans's Battery of two 9 oke howitzers (corresponding to English 24-pdr. howitzers) was constructed of turf, with 3 embrasures and one large platform. These howitzers

* The Turkish oke weight is as near as possible 2¾ lbs.

flanked the Mosque and Advanced Batteries, commanded the approaches to the main sally-port, and searched such ground as was hidden from the direct fire of the Advanced battery.

The Advanced and Evans's batteries were connected by an irregular indented parapet and pointed ditch, adapted to the irregularities of the ground, and crowning the summits of such tumuli as came into its trace with breast works for sharp shooters.

From Evans's to the Mosque Battery the line was broken by two short flanks, in which were embrasures revetted with casks, and provided with stone platforms for field-pieces. Between the Mosque and Evans's Batteries was the principal sally-port, which was well protected by a cross fire of musketry from loop-holed huts, and by a gun at the traverse, sweeping a moveable drawbridge.

The Mosque Battery on the extreme right of this front mounted 3 (9 oke) guns; it was important from its position as it fronted the rising ground outside, from which, when in the enemy's hands, their guns could have annoyed the defenders of the north front and enfiladed the main road of communication with the town. The parapet of this battery was 18 feet thick, and the interior crest 12 feet high; the ditch was 21 feet wide and 12 feet deep, with steep escarp and counterscarp; the guns were on low raised terrepleins, and fired through embrasures, the cheeks of which were revetted with two tiers of casks, over which raw hides were spiked, forming a sufficiently firm and fire-proof revetment. The interior slope of the parapet was built of large stones laid dry for a thickness of 4 feet in the merlons; this revetment had the support of a banquette in two treads, the upper one being the top of a $3\frac{1}{2}$ feet wall, also built up dry from the ground. There were two bomb-proof magazines in this battery, one in the banquette, the other in the left epaulement.

Along the whole of the front, from Evans's to Mosque Battery, the glacis had to be cleared of the Tartar habitations, which thickly covered it; the ruins furnished the troops with plenty of fuel.

Southern Front.

The Southern Front, commencing at the Advanced Battery and terminating on the bay across the Fort Paul Road, extended along the crest of the range of hills above Kertch, whence it descended rapidly to the bay, round the blocks of houses. The hill line of trench was of slight relief, owing to its elevated position. It was in many points rendered inaccessible to infantry by steep scarps cut wherever the natural formation of the rocks admitted of it.

The front was defended by a large redoubt and two batteries, viz:—

1. The Howitzer Battery of 1 ($11\frac{2}{3}$ oke) howitzer with 1 magazine.
2. The Hill Battery of 2 24-pdr. guns with 1 ditto.

The Howitzer Battery was on a point rather in advance of the line, half way between the Advanced and Hill Batteries. It was constructed on the top of a tumulus, which was crowned with a circular breastwork, over which the Howitzer fired in any direction, and the sides were scarped. The steep high scarp under Vivian's Hill was flanked by this piece, and some little valleys hidden from the Hill Battery could be searched by it. Its magazine was formed in the interior of a tumulus in rear.

The small number of guns available necessitated a departure in this instance from the rule not to leave a gun single; its position, moreover, lessened the risk that might otherwise have existed.

The Hill Battery was placed on a large elevated plateau, and consisted of two 24-pdrs. firing over low breast works, the continued line passing below them. These guns commanded the valley to the south, and could also be turned against any point beyond the north front. There was a large magazine behind this battery and below it. The original intention was to construct a redoubt on this plateau, and connect it with the town defences at the Griffin Gates, making an interior line of works which would have added materially to the strength of the position ; but this could not be carried out in consequence of the difficulty experienced in constructing the more advanced works during the hard frosts of a severe winter, and of the great exposure of the working parties to the intense cold. As the weather became milder the necessity for the inner line disappeared.

The main line of this front, commencing at the Advanced Battery, was a parapet from 8 feet to 10 feet thick, with a pointed ditch 15 feet wide, where not scarped, of an irregular indented trace, and running along the crest of the range of hills. On the summit of Vivian's Hill, which was by nature very abrupt to the south, a scarp of 25 to 30 feet high was obtained, the same being flanked, as before stated, by the guns of the Advanced and Howitzer Batteries. This scarp, with a breast-work above for infantry, extended from one battery to the other : from the latter the line towards the redoubt, beyond the Hill Battery, consisted of a parapet and ditch as above described. Some very commanding points, brought into the trace of this line, gave a powerful plunging musquetry fire into all valleys and sunken water-courses hidden from the batteries.

The redoubt crowned the plateau on the top of Mithridates' Hill, which abruptly terminated the range above the bay; this work was irregular, and it was defiladed where necessary from the higher ground of the Hill Battery by parados. It was capable of containing 3,000 men, and being in most points unassailable, from the scarping system adopted in its construction, it was considered as a point of retreat in the event of disaster on other points; but as it was deficient in water it could only serve as a refuge whence terms might be obtained. It gave cover for working field-guns when driven to it. From two of its salients deep and wide ditches were cut and parapets constructed down the slope of the hill to the remains of the Russian store-houses in the low ground, to give protection to the Museum, which had been converted into the main magazine; and both the above obstacles were flanked from the redoubt. The main line was continued by surrounding the store-houses with a ditch, and throwing the earth against the walls, which were loop-holed and had banquettes made inside. Barbettes for field-guns were also constructed to sweep the Fort Paul Road, which entered the lines at a sally-port on the margin of the bay.

Northern Front.

The north front, in the marshy valley before mentioned, commenced at the Mosque Battery, and, surrounding the town, terminated at the Causeway Battery on the Yeni-kaleh Road. From the former to the Griffin Gates the parapet was high and strong, the trace being that of a regular redan line. The salients rested on tumuli which formed natural terrepleins for field-guns. The salient near the Mosque Battery contained a barbette which was covered by a high traverse revetted with casks in four tiers ; an embrasure was also pierced to flank the right face of the Mosque Battery. The earthen parapet of the redan line, 15 feet thick, was revetted by a wall of loose stones 3 to 4 feet thick and 12 feet high, with a banquette in two treads with steps to each ; the ditch was 21 feet wide at the top and 15 feet deep. This parapet was made high to cover mounted transport passing along the road from the town to the camp and batteries of the western front.

The works round the town from the Griffin Gates were similar to those before described, thrown up against the store-houses on the south; the line was disposed so as to cover such houses and walls as were best adapted for obtaining flank defence, and so as to lose no quarters for the troops. The whole of the ground in front was well cleared of other buildings. An additional defence to this front was the canal just outside of it, which had been constructed by the Russians to drain the marshes in the northern valley; to render it more available all the bridges over it but one were demolished. The salient points were converted into barbette batteries for the reserve artillery guns, and named Holmes's Bastion, Crease's Redan, and Canal Redan; in the gorge of Holmes's Bastion was a large well-built house which was rendered defensible in the usual manner.

The Causeway Battery, before mentioned as terminating this front, was planted across the Yeni-kaleh Road. It was entirely constructed by the Turkish soldiers selected from the various regiments of infantry to form a native Engineer Corps: the workmanlike and substantial manner in which the sea wall of this battery, as well as the interior revetments, traverses, and magazine, were built by them, promised highly for the value and efficiency of the Turkish Engineer Corps.

Three light guns and one howitzer constituted the armament of this battery: two guns swept the Yeni-kaleh Road, one commanded the rising ground of Windmill Hill, and the howitzer served to flank the northern front.

Interior Defences.

The interior defences consisted of the following detached batteries situated on the rising ground above the town:

1. Allan's Battery of 2 32-pounders, with 1 magazine.
2. Spur ,, 2 24-pounders, with 1 ,,
3. Stephens's ,, 1 9 oke gun, with 1 ,,
4. Maquay's ,, 2 11 oke guns, with 1 ,,

Allan's Battery was on a spur facing north, a little below the Hill Battery: the two British 32-pdrs., mounted on large platforms, fired over a low breastwork commanding every point beyond the north front, besides taking the same and Holmes's Bastion in reverse.

Spur Battery, a little lower than the former and of similar construction, could be used in the same manner.

Stephens's Battery, with its 9 oke gun, defended all approaches internally and externally to the Pentecost Street Sally-Port. It was constructed in a yard which was retained by a high masonry wall.

Maquay's Battery, on the edge of a precipitous scarp, took the batteries at the salients of the town defences in reverse, and commanded the market place. The two 11 oke guns mounted "en barbette" had a very extended lateral range and searched all valleys about the Windmill Hill.

Having described the land defences, in estimating the strength of the position the auxiliary fire of the gunboats must not be omitted. From their light draught they could come close to the shore and enfilade the northern and southern valleys, flanking those fronts most effectually, thus leaving an attacking force little choice but the western and strongest front, without exposure to many losses from so powerful a flank fire as could be obtained from these moveable batteries. In mid-winter, however, the bay being frozen and but one gun boat (H. M. S. Weser) available, this vessel was stationed so as to flank the northern defences. She was armed with 4 68-pdrs. and 2 32-pdrs.

The following table contains a summary of all the batteries described, with their armaments, &c.

Name of Battery.	No. of pieces of Ordnance.	Description of Ordnance.	Magazines.	Embrasures.	Barbettes.	Platforms.	Remarks.
Advanced Battery	3	1 24-pdr. British 2 9 oke guns	1	4	1	5	
Lyons's "	1	11 oke gun	-	1	-	1	
Mortar "	4	8-inch mortars	2	-	-	4	
Evans's "	2	9 oke howitzers	1	3	-	1	Platform all in one piece.
Mosque	3	9 oke guns	2	3	3	3	Platform all in one piece.
Howitzer	1	$11\frac{2}{3}$ oke howitzer	1	-	-	-	
Hill "	2	24-pdrs. British	1	-	-	2	
Causeway "	4	3 5 oke guns 1 9 oke howitzer	1	4	-	4	
Allan's "	2	32-pdrs. British	1	-	-	2	
Spur "	2	24-pdrs. do.	1	-	-	2	
Stephens's "	1	9 oke gun	1	-	-	1	Lean-to mag^{e}
Maquay's "	2	11 oke guns	1	-	-	2	
Total......	27	11 British 16 Turkish	13	15	4	27	

Details.

The expense magazines of the above batteries were all of the rectangular field magazine form (except the lean-to in Stephen's Battery). They were made with four frames 3 feet 6 inches by 6 feet: others were introduced for passages where required, the points of bearing for the bomb-proof timbers being between 8 and 9 feet apart. These dimensions gave an interior space of about 350 cubic feet. Over the bomb-proof beams was laid a tier of sand bags and 5 or more feet of earth; all the magazines were well floored with deal. The bomb-proof timbers were of oak 12 in. × 12 in.

The Museum was converted into the main magazine: it was quite sheltered from any fire from an enemy, as well as removed from danger arising from casual fires in the town. The Engineers made it weather-tight for the reception of powder, and converted several vaulted chambers under the great stone flight of stairs leading to it into suitable and secure magazines for the same purpose.

The materials used in the batteries for the magazines and platforms were in part collected from ruined houses in and about the town; the oak was bought at Varna when the Engineer Corps of the Contingent landed there in September, 1855; much pine timber came from Constantinople for engineering purposes in the form of scantling and planking, and some good baulks were selected from what the gun-boats took out of Taman, a town on the opposite side of the Straits.

The description of the Engineer Force of the Turkish Contingent, under whose supervision the works were constructed, will be found in Major Stokes's paper on that subject, as well as a report on the equipment of that force.

The defensive works of Kertch were thrown up in four months, during a severe winter, and the following is an outline of the system adopted in constructing the same. Every regiment had a part of the lines appropriated to it, and each company a subdivision of the same. Two or three hundred sets of entrenching tools were issued to each regiment, and the working parties supplied varied from 400 to 500 men per regiment; men from each company were detached to make up the number, and the working hours were from 8 till 12 A.M., and 1 till 5 or 6 P.M. As is usually done, the Engineer officer in charge erected the necessary profiles and marked out the ditch with tracing line; the native officers of regiments were instructed in the object and nature of the work to be thrown up, and they then settled the subdivision of the tasks and set to work.

The blasting, construction of magazines, and such like duties, were performed by the English Engineers, who soon became well acquainted with the general principles of field works, and were instructed in the same by their officers who had every reason to be satisfied with the rapid progress made by them. These men, previously to their landing in the Crimea, were mechanics and artificers totally ignorant of military engineering, and but very imperfectly disciplined. The Turkish working parties were found to be very manageable through their native officers, who, in all cases of pressure of work, showed a willingness to assist the English officers in carrying out their wishes. For 6 weeks out of the four months of work, the whole of the regiments were on the works as strong as they could muster, to the number of about 4,000 men on the advanced fronts, and about the same number on the town ramparts.

The writer is not in possession of an exact Return of the garrison, but the following may be accepted as a fair approximate estimate of the force—

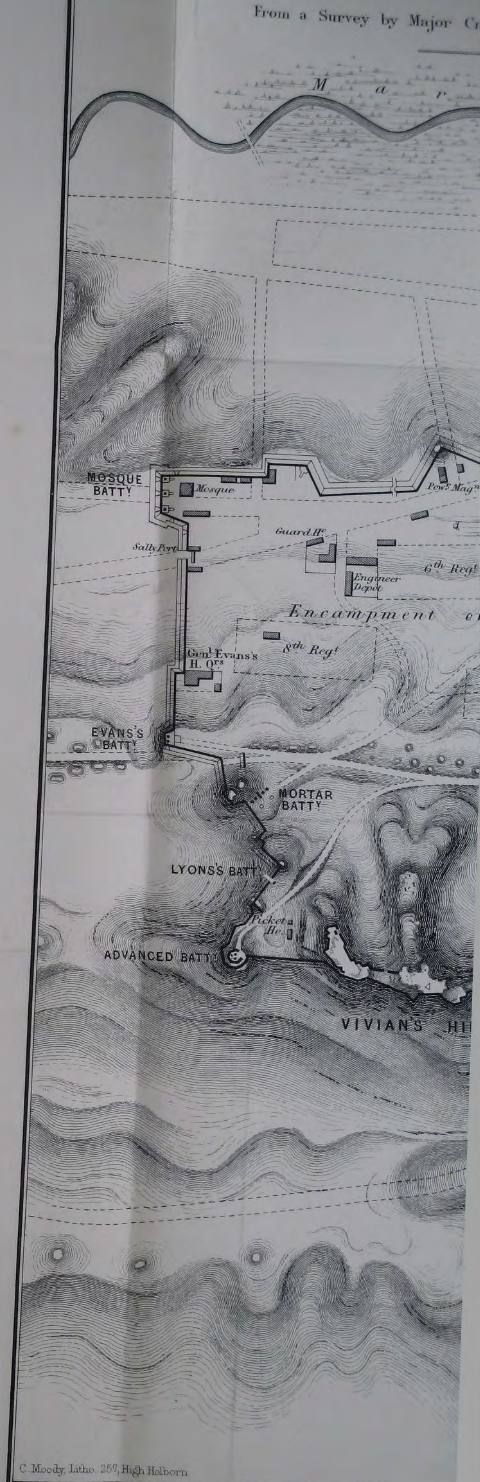
Infantry—	10,000	Turkish soldiers in 10 Regiments.
	130	Engineers.
	200	of the 71st Highlanders.
	100	French Marines.
	10,430	men.
Cavalry—	100	Turkish Contingent Cavalry.
	80	of the 10th Hussars.
	40	Chasseurs d'Afrique.
	40	Tartar Militia.
	260	men.
Artillery—	1,430	Gunners and Drivers, both for field batteries and siege train.
	30	Field guns (horsed).

Giving a general total of 12,120 men available for the defence of the place.

5,000 men and two field batteries were cantoned between the town and the western front. The rest were quartered in the town itself.

The cantonment was laid out by the Engineers; the Turks excavated and built the walls of their huts, and, with the assistance of some Engineers, covered them with simple roofs of planks and tarpaulins.

Besides the 27 guns in position there were a few more heavy brass howitzers and guns as a reserve. The field batteries of the force were 6 in number with 1 troop of Horse Artillery. All but one of these had 3½ oke guns, corresponding to our 9-pdrs., and the other was a 4¾ oke or 12-pdr. battery. These were well horsed and appointed, this being the most perfect branch of the Turkish service. The troop had 2½ oke guns. Two of the 9-pdr. batteries were in the lines of Yeni-kaleh and formed part of its garrison.


From a Survey by Major Gr
M a r
MOSQUE BATTY
Mosque
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EVANS'S BATTY
MORTAR BATTY
LYONS'S BATTY
Picket Ho.
ADVANCED BATTY
VIVIAN'S HI
C. Moody, Litho. 257, High Holborn

The Positions of Yeni-kaleh and Fort Paul.

As was stated in the commencement of this Paper, the positions first occupied by the allies were Fort Paul and Yeni-kaleh. They were fortified by earth-works, and from their situation, as commanding the Yeni-kaleh Straits or Cimmerian Bosphorus, connecting the Black Sea with the Sea of Azov, could not be neglected. As before stated they were not tenable by a large force from the scarcity of water.

Fort Paul had a continued line of parapet, and enclosed a space containing 1,500 Turks, 1,500 French Marines, and a company of Royal Artillery.

These troops were all hutted during the winter. The lines were strong, connecting large tumuli, the summits of which were converted into batteries. There were 17 heavy guns mounted in this position. This fort, about a quarter of a mile from the original Fort Paul, blown up by the Russians, on the point of Ak Burnu, covered the best landing place on the whole coast; it was supplied with water for the troops by a small condensing apparatus put together by the British Navy, and made up of machinery taken from the Russian manufactories destroyed at Kertch.

Yeni-kaleh was a small fishing village with an old Genoese castle, beyond which the allies threw up an indented line of works for further security. A garrison of 3,000 Turks, and 2 field-batteries of 3½ oke guns, were hutted between the castle and the outer line. There were some fine Russian guns mounted on the castle ramparts, which were made serviceable, and, altogether, the position mounted 52 guns, including the field-pieces. The water for this garrison came in earthenware pipes from a spring some way inland, and was collected in a spacious cistern in one of the towers of the old castle; the supply however was precarious at all times, and sometimes ceased altogether.

(Signed) J. P. MAQUAY, Lieut. R.E.

PAPER III.

Report on the Demolition of a part of the Nawab's Fort at Furruckabad, in January, 1858.

By LIEUT. SCRATCHLEY, Royal Engineers.

The part of the fort ordered to be destroyed was a front built of good sound brick masonry, consisting of two solid towers (the left one being 54 feet in height and the other 36 feet high, and both being 54 feet in diameter,) connected by a revetted curtain 130 feet long and 34 feet in height; two portions of revetment, 30 feet in length, running at right angles to the curtain, from the towers on each side, and of nearly the same height as the curtain; and also a wall 160 feet long, 11 feet high, and 2 feet thick, forming part of an enclosed courtyard. The mines were ordered to be ready for explosion in 48 hours.

The project for the demolition of the front was as follows:—2 charges, with lines of least resistance 18 feet long, to be placed in each of the towers, three feet in advance of their centres, and at one lined intervals. (See the accompanying plan of the Fort.) Two charges, with LLR = 12 feet, to be placed in each tower in rear of the angles formed by the tower and the revetment. The remaining portion of the connecting curtain to be destroyed by charges with LLR = 10 feet, placed at $2\frac{1}{2}$ lined intervals, which required 6 more.

In the towers, galleries, with returns, were to be driven at nearly equal levels (which the nature of the ground favoured.) The mines in the revetment were to be formed by sinking 5 shafts, each 15 feet deep, with galleries running out right and left from them to the requisite distances.

The charges were calculated according to the formula for strong masonry revetments without counterforts, placed at two lined intervals, or $\frac{3}{20}$ LLR^3. As native powder was to be used, I allowed $\frac{1}{5}$ of $\frac{3}{20}$ LLR^3, or $\frac{3}{100}$ LLR^3, in addition to the proper charges of English powder, making the formula $\frac{3}{20}$ LLR^3 + $\frac{3}{100}$ LLR^3 = $\frac{18}{100}$ LLR^3.

I was also directed to prepare the towers at the entrance gateway for demolition, and I proposed and carried out the following plan. These towers were 28 feet in diameter, and from 22 feet to 29 feet high on the outside: they were built of softer masonry than the others, and were solid only to a height of 15 feet from the bottom. A shaft was to be sunk in the centre of each tower, at the level of the ground inside (15 feet from the bottom) 12 feet deep; and small galleries were to be driven right and left, 5 and 6 feet long respectively. The charges were calculated, as above, by the formula $\frac{18}{100}$ LLR^3, and were to be placed so that their lines of least resistance were respectively 8 and 9 feet long.

The following journal will show the details of the work executed.

The following detail of officers and men of the Engineer Brigade left the camp at Futtehghur at 3 P.M., 5th Jannuary, 1858 :—

Corps.	Officers.	Native Officers.	Sergeants.	Corporals.	Privates.	Buglers.	Total.	Remarks.
Royal Engineers	3	-	2	5	52	1	63	Lieut. Scratchley, R.E.
Bengal Engineers	2	-	-	-	-	-	2	„ Wynne, R.E. „ Keith, R.E.
Bengal Sappers and Miners	-	2	4	-	33	-	39	„ Lang, B.E. „ Forbes, B.E.
	5	2	6	5	85	1	104	

This detail was divided into 3 reliefs, viz. :—

1st relief—20 rank and file European.
12 „ Native.
2nd relief—19 „ European.
12 „ Native.
3rd relief—18 „ European.
12 „ Native.

The 1st relief commenced work at 8 P.M. on the evening of January 5th.

January 5th, 1st Relief, 8 till 12 P.M , Lieutenant Wynne, R.E.—4 galleries, marked B, C, G, H on plan, were commenced in the towers at the respective levels of 26′ 6″, 27′ 6″, 29′ 6″, and 29′ 6″, below the terreplein of the fort, and driven towards the centre of each tower. 4 shafts, A, D, E, F were also commenced at a distance of 10 feet from the curtain wall.

January 6th, 2nd Relief, 12 till 4 A.M , Lieutenant Keith, R.E —Shafts A, D, E, F were completed to the depth of 15 feet each, and were made 4 ft. by 3 ft. Galleries running parallel to the wall were commenced right and left of each shaft. Soil very easy, being made earth. Galleries B, C, G progressed slowly through very tough pucka masonry. That at H was softer.

3rd Relief, 4 till 8 A.M., Lieutenant Lang, B.E.—The eight galleries of A, D, E, F progressed rapidly through made earth. The galleries B, C, G advanced through tough masonry, and H through soft masonry. The tools were in bad order and were not adapted to mining.

1st Relief, 8 till 12 A.M., Lieutenant Forbes, B E.—The eight galleries progressed rapidly. The gallery H was cut through pucka masonry, 7 feet, and reached rubble. The progress at B, C, G was slower.

2nd Relief, 12 till 4 P.M. Lieutenant Wynne, R.E.—The eight galleries were nearly finished—

That at B had advanced 9 ft. 0 in. through pucka masonry.
„ C „ 8 ft. 6 in. „
„ G „ 3 ft. 0 in. „
„ H „ 12 ft. 0 in. through made earth.

3rd Relief, 4 P.M. to 8 P.M , Lieutenant Keith, R.E.—The galleries of A, D, E, F were finished to the following lengths :—

A *c*	(see plan)	12 ft. 0 in.	E *c′*	(see plan)	12 ft. 6 in.
A *b*	„	13 ft. 6 in.	E *c*	„	12 ft. 6 in.
D b^1	„	14 ft. 0 in.	F *c*	„	12 ft. 6 in.
D *c*	„	12 ft. 6 in.	F b^1	„	20 ft. 0 in.

Hardly any progress was made at G.

1st Relief, 8 till 12 P.M., Lieutenant Lang, B.E.—Another shaft I (see Plan) was commenced at a distance of 10 feet from the wall. A party was also employed in lodging charges in the wall to be destroyed, (described in accompanying memorandum).

January 7th, 2nd Relief, 12 P.M. till 4 A.M., Lieutenant Forbes, B.E.—

B gallery was 24 feet long.
C „ 24 „
H „ 17 ft. 10 in., and return commenced.
G had not extended through pucka masonry.

3rd Relief, 4 till 8 A.M., Lieutenant Wynne, R.E.—Shaft I was completed to a depth of 15 feet, and two galleries were commenced from it, running right and left parallel to the wall.

1st Relief, Lieutenant Keith, R.E.—The galleries of shaft I were completed to the required lengths, viz., I b'', 14 feet, and I *c*, 12 feet. Chambers were formed in all the shaft-galleries.

B gallery was completed, with a return 5 ft. 8 in. long.
C „ „ „ 7 ft. 0 in. „
At G the work was continued by blasting.
H gallery was completed, with a return 6 feet long.

2nd Relief, 12 till 4 P.M., Lieutenant Lang, B.E.—The chambers in all the galleries except G were completed. G was 8 ft. 5 in. long, pucka masonry, 7 feet thick, having been cut through. More experiments were made on the wall of the court-yard.

3rd Relief, 4 till 8 P.M., Lieutenant Forbes, B.E.—More charges were tried on the wall, and a party was employed destroying it by hand.

1st Relief, 8 till 12 P.M., Lieutenant Wynne, R.E.—Shafts A and B were sunk 12 feet deep in the entrance towers.

8th January, *2nd Relief*, 12 till 4 A.M., Lieutenant Keith, R.E.—Galleries were driven from shafts A and B, right and left, 7 feet and 9 feet long respectively.

3rd Relief, 4 till 8 A.M., Lieutenant Lang, B.E.—A party of men was employed in demolishing the wall. Chambers were prepared and bamboos laid (as in all the other mines) for the entrance tower mines. The whole of the mines were now ready for loading, but the powder had not yet arrived.

9th January.—At 3 P.M. this afternoon the party of Engineers, after carefully closing all the openings of the shafts and galleries, was marched back to Futtehghur camp.

Remarks.—The whole of the work had thus been carried on without interruption, the soil being very easily worked, and being evidently all made earth. No sheeting had been required, excepting in the left gallery at the right entrance tower, where the earth fell in. The whole of the mines were ready for charging *in 48 hours*, with the exception of that in gallery G, where the pucka masonry gave great trouble. The dimensions of all the galleries were 3′ 6″ by 2′ 6″.

13th January.—A detail of the Engineer Brigade left camp at 5·30 A.M. to load the mines at the Fort, viz., Royal Engineers, 2 officers, 2 sergeants, and 82 rank and file; Bengal Engineers, 1 officer, and 24 native sappers. Twelve of the native sappers were however afterwards withdrawn to be employed elsewhere.

The charges were placed as follows :—

In B gallery at a^1		1050	lbs. of	Native powder.
C gallery at *a* ...		800	-	English -
		99	-	Native -
G gallery at *a*		874	-	English -
H gallery at a^1		1050	-	Native -
A shaft	at *c*	180	-	- -
	at *b*	310	-	- -

D shaft	at b^1	310	„	„	„
	at c	180	„	„	„
E shaft	at c′	180	„	„	„
	at c	180	„	„	„
F shaft	at c	180	„	„	„
	at b^1 ..	258	„	English	„
I shaft	at b^2 ..	258	„	„	„
	at c	180	„	Native	„

The charges were placed in boxes where practicable, the hose was laid in bamboos, and the whole was carefully tamped.

The galleries took most time in loading and tamping, and were not ready till 7 P.M., whilst the shafts were finished by 4 P.M.

The firing was put off till the next morning, when the hoses of all the shafts were brought to one focus, R. There was one focus for each tower, the length of hose for each being 5 feet less than that for the upper focus, to allow, if possible, a few seconds elapsing between the two explosions. The hose was lighted at the three foci at the same time, at the sound of the bugle, and the explosions were very nearly simultaneous, with the exception of that of one mine (marked X on the plan), which did not take place till 30 seconds after the others.

The demolition was complete, and the object desired was attained, which was to leave a pretty practicable ramp from the outside into the interior.

There is no doubt that if more time had been allowed, or more men had been procurable, the demolition might have been effected by the expenditure of one-half of the quantity of powder used; but it must be borne in mind that my instructions were to have everything ready *in 48 hours*, and I understood that native powder was to be had in abundance.

The mines at the entrance gateway were not loaded, but remain ready to be charged at some future time.

P. H. SCRATCHLEY, Lieut. R.E., in charge.

26th January, 1858.

STATEMENT OF THE EXPENDITURE OF POWDER, HOSE, &c.

2 charges of 1,050 lbs. each, total 2,100 lbs., Native powder.

1	„	874	„	„	1,674 lbs., English	„
1	„	800	„			
		99	„	„	99 lbs., Native	„
6	„	180	„	„	1,080 lbs., „	„
2	„	310	„	„	620 lbs., „	„
2	„	258	„	„	516 lbs., English	„

Total 2,190 lbs. of English powder.

„ 3,899 lbs. of Native „

„ 848 feet of ½-inch hose.

„ 2 portfires.

Memorandum on the Partial Destruction of a Wall at the Nawab's Fort at Furruckabad, by means of Small Charges.

This wall was evidently of some years standing, 11 feet high, 2 feet thick, and about 160 feet long. There were two piers, 6 feet square, one on each side of an entrance at the centre of the wall; these were built much better than the remainder of the wall, which had been constructed with bricks and a little mud, mortar being found only in the foundation.

10 charges, of 5 lbs. each, were placed along the wall, at intervals of 10 feet, and were lodged as nearly as possible 2 feet below the surface of the ground, and under the centre line of the wall. One charge of 10 lbs. was placed in each pier, 2 feet 6 inches below the level of the ground, and under its centre.

The piers were completely thrown down, without violence: all the other charges, with the exception of three, failed, some blowing out the tamping and making a small breach in the wall, others throwing out the foundation and earth on the other side, but failing to bring down the wall, or any part of it. I therefore placed four more charges of 5 lbs. each, equi-distant between the former, which completely destroyed the part where they were lodged.

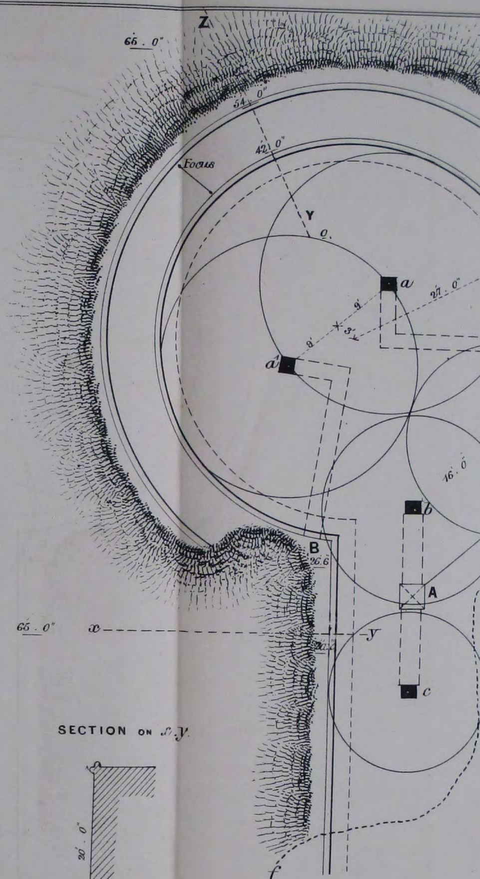
The remainder of the wall was picked and thrown down by about 12 men in a very short time, and other portions of the walls around were thrown down in the same manner.

The powder made use of was native, and undoubtedly of inferior strength to that of European manufacture.

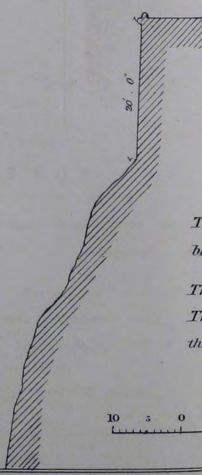
I did not try blasting, as the nature of the wall did not admit of it, and there were no men to spare of it. Had I known that it was so very rotten I would have had the whole of it picked down.

As similar walls are very frequently met with in this country, I tried the above more as experiments, wishing, if possible, to arrive at some speedy method of destroying them, when a saving of labour, time, and powder is of consequence.

P. SCRATCHLEY, Lieut R.E.



SECTION ON x.y.



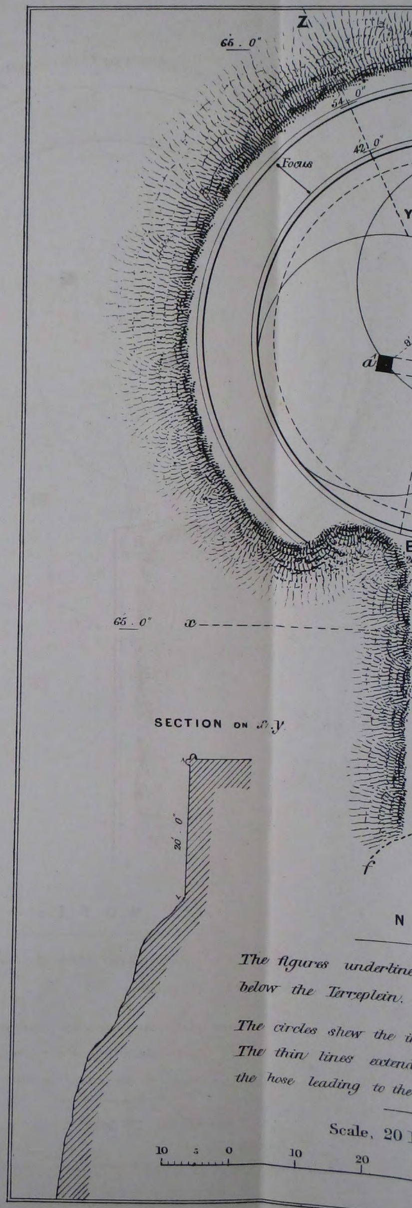
NOTE.

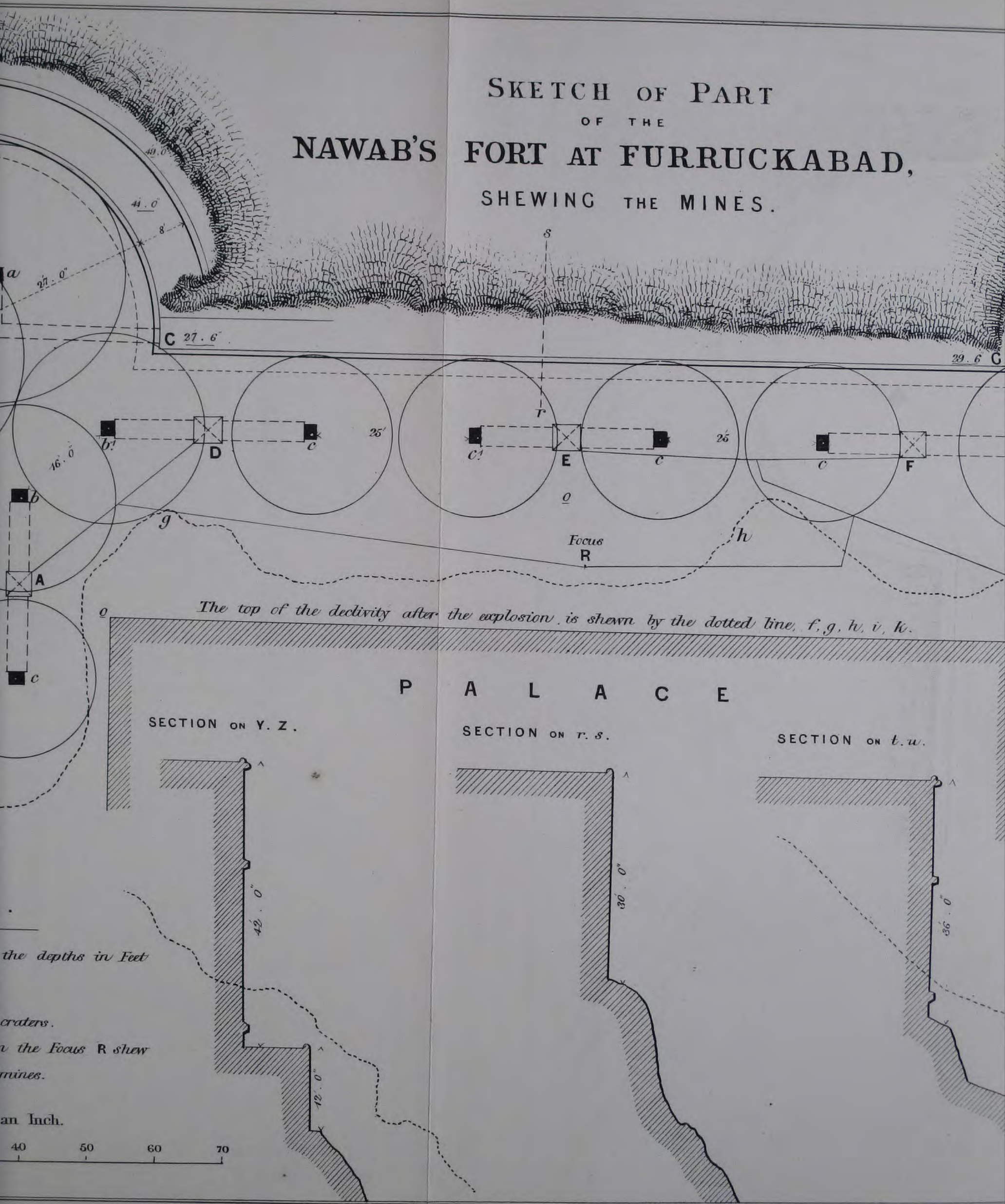
The figures underlined shew the depths i
below the Terreplein.

The circles shew the intended craters.
The thin lines extending from the Focus R
the hose leading to the upper mines.

Scale, 20 Feet to an Inch.

10 5 0 10 20 30 40 50


Z
65 . 0"
54 . 0"
42 . 0"
Focus
Y
a
E
65 . 0"
x
SECTION ON x.y
20 . 0"
f
N
The figures underline
below the Terreplein.
The circles shew the
The thin lines extend
the hose leading to the
Scale, 20
10 5 0 10 20


SKETCH OF PART
OF THE
NAWAB'S FORT AT FURRUCKABAD,
SHEWING THE MINES.
49.0
41.0
8'
27.0"
C 27.6
29.6 G
16.0
25'
A
D
E
F
Focus
R
The top of the declivity after the explosion is shewn by the dotted line, f, g, h, i, k.
P A L A C E
SECTION ON Y. Z.
SECTION ON r. s.
SECTION ON t. u.
42.0"
12.0"
30.0"
36.0"
the depths in Feet
craters.
the Focus R shew
mines.
an Inch.
40
50
60
70

PAPER IV.

On a Practical Method of Determining the Vertical Strain on a Loaded Truss.

By MAJOR COOKE, Royal Engineers.

When a beam or truss is loaded with a weight, either uniform, or applied at the centre, it is acted upon by two forces, a vertical and a horizontal one, which are quite distinct from one another, and are ruled by different laws.

It is well known that, in a beam or truss so loaded, the greatest effect of the load on the whole structure will be at the centre, and that that will be the point at which rupture will probably occur, if the load is too great for the strength of the structure. But it is not equally well known that this applies only as regards the horizontal force, and that as regards the vertical force, the case is quite different, inasmuch as, in a uniformly loaded beam, this force is actually nothing at the centre, and increases from that point to the abutment, where it is greatest, following therefore a law exactly the reverse of that which governs the horizontal force. The practical results of this are very important. It follows from it that, in a simple truss consisting of chords, ties, and braces, the ties and braces, which resist the vertical strain, should be strongest towards the abutments, those at the centre being actually useless, as there is no vertical force there to be resisted.

The existence and nature of the horizontal force is easy of demonstration; it is shown by the extension and compression of the fibres, and their subsequent rupture towards the centre, when a beam is loaded with a weight too great for its strength. The amount of the vertical force is less easy of demonstration; the theoretical proof of it is obscure and difficult, and not such as would always bring conviction to a merely practical mind, and as it is such an important element in determining the position and strength of many parts of a truss, it appeared to me desirable to make an apparatus for showing practically its existence and amount, by the use of which the student and practical engineer might be convinced at once of its nature and effects. Before describing this apparatus, I will state briefly the theory of the laws of the vertical and horizontal forces, and then show how far my experiments agree with them.

Tredgold, in his treatise on carpentry, investigates the laws which regulate the strength of loaded beams, but he makes no allusion to a vertical, as distinguished from a horizontal force, and it seems doubtful whether he ever took it into consideration, as, had he done so, he would probably have made a different arrangement of the ties in the trusses he proposes. Haupt, an American Engineer, who has written a very interesting treatise on bridge-constructions, which the gigantic works of America have given him facilities of investigating, has entered very fully into the general laws for a loaded beam, including those that affect the horizontal and vertical forces; his investigations of them are very novel and ingenious, and although they do not all bear on my experiments, it will not be out of place to commence by giving a brief outline of them.

Premising that, in a beam supported at one end and loaded at the other, the neutral axis may be taken, for practical purposes, in the centre, that the fibres in the upper half are extended, and in the lower half compressed, and that the amount of extension and compression of each fibre indicates the resistance it affords to the effects of the load on the beam, he proceeds to investigate the total effect of all the fibres in supporting the load.

Let ABCD (Fig. 1) be a beam fixed in the wall at AD, EF being its neutral axis.

It is evident that three forces are acting on the beam, (its own weight being disregarded); the load it is supporting (W), which may be supposed to be acting at F, in a vertical direction; the resistance of the fibres of the upper half to extension, which may be represented by a force W′, acting horizontally in the direction from D to O; and the resistance of the fibres of the lower half to compression, which may be represented by a force W″ acting horizontally in the direction from A to B. The beam may therefore be represented by a lever kept at rest by three forces, W, W′, W″, acting round a fulcrum E.

The size and points of application of W, W′, W″ are determined as follows:—

Let AR (=R) represent the resistance of the fibre at A to compression, then, as the resistance of all the other fibres of the lower half are proportional to their distance from the neutral axis, it is evident that they may be represented by the lines *ar*, *a′r′*, &c., and that their sum will be equal to the area of the triangle $AER = \frac{d}{2} \times \frac{R}{2} = \frac{dR}{4}$ (where d=AD). Any number of parallel forces may be replaced by a single force called the resultant, and in the present instance, the resultant of the forces composing the triangle AER will be a force equal to the area of the triangle, acting at its centre of gravity, in a direction parallel to AR. The position of the centre of gravity, G, is easily determined, and EK will be found $= \frac{2}{3}$ EA $= \frac{1}{3}d$.

The magnitude and direction of the weight W′ may be found in precisely the same way.

Regarding E as a fulcrum, we have 2 forces, each equal to $\frac{dR}{4}$, acting with a leverage, $\frac{1}{3}d$, on the one hand, and the weight W, acting with a leverage l, on the other. The equation of equilibrium will therefore be $\frac{d^2R}{6} = Wl$, and taking the breadth (b) into consideration, $\frac{Rbd^2}{6} = Wl$.

To determine the weight which the beam can support without injury, R must be taken equal to the greatest strain which a square inch of the material will bear without destroying its elastic force; this can only be found by experiment.

The strains, for beams loaded and supported in different ways, are determined in the same manner, and agree with those arrived at by Tredgold. In comparing the two, it must be borne in mind that the length is taken by Tredgold in feet, and by Haupt in inches.*

The following is the reasoning by which Haupt determines the horizontal and vertical forces acting on a beam:—

Let AB (Fig. 2) be a beam supported at A and B, and loaded at E. We may regard it as a lever acted upon by two upward forces at A and B, caused by the resistance of the abutments, each equal $\frac{1}{2}$ W, E being the fulcrum. The moment of each of these forces, acting with the leverage $\frac{1}{2}l$ (=DE or EC), will be $\frac{1}{2}W \times \frac{1}{2}l = \frac{Wl}{4}$. The moment of the horizontal force H (representing the resistance of the fibres) acting with the leverage d, will be Hd;

$$\text{whence } Hd = \frac{Wl}{4} \text{ and } H = \frac{Wl}{4d}.$$

* On the value, in different woods, which may be taken for R, with safety, Haupt and Tredgold are at issue, the former only allowing a quarter of that given by the latter. Few will doubt that the values, as given by Tredgold, are too large.—A. C.

To determine the Horizontal Strain at any other point.

Continuing the same reasoning as before, regarding the weight $\frac{1}{2}W$ as acting upwards at C, (Fig. 3) the fulcrum being at S, and putting SC = U, the moment of forces becomes— $\frac{1}{2} W \times U = Hd$

$$\therefore H = \frac{UW}{2d}, \text{ which becomes, when } U = \tfrac{1}{2}l,$$

$$H = \frac{Wl}{4d}, \text{ as before.}$$

The horizontal strain in the middle of the beam is therefore to the same strain at any other point as $\frac{l}{2}$ to U, and varies with the perpendiculars of a triangle constructed on $\frac{l}{2}$ as a base.

To determine the Vertical Strain.

The horizontal force at S was found to be $\frac{UW}{2d}$, but it is evident that the portion of the beam DS, with the applied weight at E, presses against the cross section at S, and must be resisted by the reaction at that point. If the horizontal force $\frac{UW}{2d}$, acting with the leverage d, were sufficient to sustain the part DS, the effect of the weight at E would be entirely overcome, and there would remain nothing to produce a downward strain upon the fibres at S, or in other words the vertical strain would be zero; that this is not the case however can be seen by estimating the force necessary to sustain DS in equilibrium. As W acts with a leverage DE or AN, the equation of moments will be

$$H'd = \frac{Wl}{2}$$

$$\text{or } H' = \frac{Wl}{2d}$$

but we have seen that the horizontal strain at S is actually $H = \frac{UW}{2d}$

the difference is $H' - H = \frac{W}{2d}(l - U)$

As this expression cannot become zero for any point between E and C, it follows that the horizontal force is not sufficient to sustain the weight, and there must consequently be a cross strain upon the fibres, which must compensate for this deficiency and be resisted by a vertical re-action. Call this vertical force f; it acts with a leverage $DS = l - U$, and the difference of the horizontal forces, or $H - H'$, acts with a leverage $= d$. The equation of moments will therefore be $f\,(l - U) = d\,\frac{W}{2d}\,(l - U)$, from which $f = \frac{W}{2}$, or the cross strain upon the fibres produced by a weight applied at the middle, is constant and equal to $\frac{1}{2}$ the weight.

In the same manner, when the weight is uniformly distributed, the horizontal strain at the middle is found to be $H = \frac{Wl}{8d}$, and the vertical force is found to be, at the centre, equal to zero, at each end equal to $\frac{1}{2}$ W, and in the intervals proportional to the distance from the centre.

Haupt then proceeds to apply these principles to trusses, and here he seems to fall into an error as to the amount of the vertical force, by not fully taking into consideration the different conditions of a truss and a solid beam.

In Fig. 4, ABCD represents a truss, consisting of chords AB, CD, ties *ee*, braces *ff*, and counterbraces *gg*.

Taking the case of a truss uniformly loaded, as most applicable to bridges and roofs, the results of the principles investigated will be, that the strain on the chord CD will be one of compression, and will be greatest in the centre, and diminish towards the abutments, where it will be zero; the strain on the chord AB will be one of extension, following the same law as that on CD; the strain on the centre tie will be nothing; and that on every other one will increase as the distance from the centre.

As regards the actual strain on each tie, we have seen that in a solid beam the vertical strain at the abutment is $\frac{1}{2}$ W, and Haupt seems to consider that the strain on the end tie of a truss will also be $\frac{1}{2}$ W. (This is nowhere expressly stated, but it may be gathered from his examples, especially in page 118; he seems however to have kept more in view the relative than the actual pressure.) This however does not agree with my experiments, nor will it stand investigation, for it is evident that the vertical strain on each tie will be transmitted by the lower chord to the abutment; and if the vertical pressure transmitted by the end ties on each abutment were $\frac{1}{2}$ W, the total pressure would exceed that amount, a result manifestly absurd.

The following, I believe, expresses the actual pressure on each tie:

Let $l =$ distance from centre of truss to abutment.

l' l'' l''' &c. = distances of the several ties from the centre, beginning at that nearest the end one.

W = Weight on half the truss.

x = Vertical pressure on the end tie.

x' x'' x''' &c = vertical pressure on the other ties, beginning at that nearest the end one:

Then the equation that expresses the pressure will be

$$x\left(1+\frac{l'}{l}+\frac{l''}{l}+\frac{l'''}{l}+\text{\&c.}\right)=\text{W}$$

from which x is obtained

$$x' = \frac{l'x}{l}$$

$$x'' = \frac{l''x}{l}$$

$$\text{\&c.} = \text{\&c.}$$

from which the strains on the other ties are obtained.

The apparatus, by means of which I found practically the vertical pressures on the ties, is shewn in the Plate. AB, CD (Fig. 5) represent the lower and upper chords of a truss. The lower chord is supported on the iron pins K, L. The upper one rests on the ties E, F, G, H, I. The construction of these ties is shown in the enlarged view of one of them (Fig. 6). MN is a hollow brass cylinder, within which is a spiral spring. OS is a wooden cylinder, to the top of which the spring is attached; it moves freely within the brass cylinder, compressing the spiral spring. Longitudinal grooves are made in the brass cylinder, in one of which slides an index, Q, fixed on the side of the wooden cylinder near the top. The side of this groove is graduated with a scale of pounds determined by experiment. Within the wooden cylinder, a metal screw TR works, by means of which the whole apparatus is lengthened or shortened.

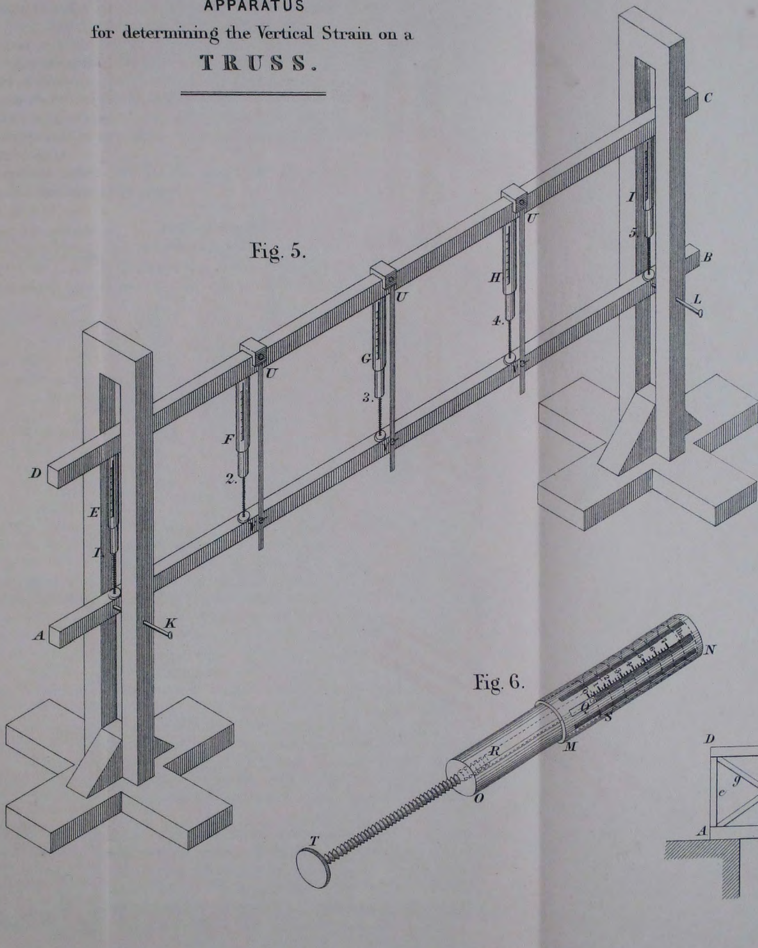
Before the truss is loaded, the exact distance between the chords, at every point where a tie is placed, is ascertained; this is best done by fixing a brass scale U to the upper chord, with a small adjusting apparatus V at the lower end, by means of which an index on the brass scale can be made to coincide with a mark on the lower chord. The spring ties are then introduced and the upper beam loaded. It is evident that, directly the weight acts on the springs in the ties, the ties will be shortened in proportion to the

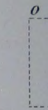
APPARATUS

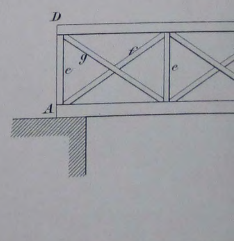
for determining the Vertical Strain on a

TRUSS.

Fig. 5.







C. Moody, Litho. 257 High Holborn.

amount of weight which they bear. In order to bring them to the condition of incompressible ties, their lengths must be adjusted by means of the screws, until they have regained their original lengths, which will be ascertained by seeing that the index on the scale coincides again with that on the lower chord. The vertical strains can then be read off on the scales of the brass cylinders. These adjustments take some time, as when any tie is lengthened or shortened, the whole of the others are affected and will require re-adjusting. It will be found that, to whatever extent the ties are lengthened or shortened, the sum of the pressures indicated by the scales will equal the total load on the bridge.

The following table shows how far the results of experiments agree with those obtained from the equation before given :—

Experiments.	Distance of Ties from Centre.		Pressure on each Tie.		Total Load.
			By Experiment.	By the Equation.	
		Inches.	lbs.	lbs.	lbs.
1.	1.	17	2·75	2·7	7·4 Uniformly distributed.
	2.	6	1	1	
	3.	0	0	0	
	4.	6	1·1	1	
	5.	17	2·6	2·7	
2.	1.	17	2·3	2·2	7·4 Uniformly distributed.
	2.	10	1·3	1·4	
	3.	0	0	0	
	4.	10	1·6	1·4	
	5.	17	2·3	2·2	

The results of practice and theory here agree quite as nearly as could be expected with the rather rudely constructed apparatus which I employed.

These results are very curious and important. They show that a tie in the centre of a uniformly loaded truss is actually useless, adding to the weight of the structure without increasing its efficiency, and that the ties and braces should be crowded towards the extremities, which is contrary to what obtains as regards the chords, which should be strongest in the centre. By the use of this apparatus these facts will be self-evident to those to whom perhaps the theory alone would not carry conviction. Other facts also come out in the use of it. By letting down one of the screws, the effect that a defective joint or bad workmanship in one of the ties has, in throwing the weight unduly on other parts of the structure, is clearly shown. It becomes evident also that, in a uniformly loaded truss, much more care is required in the construction of the joints towards the ends than near the centre, as two or three turns of the screw, in one of the ties near the end, will relieve it of as much weight (which will be thrown on some other portion), as double or treble the number in one near the centre, showing that an open joint near the abutment might throw a very undue portion of the weight on other parts of the structure.

An apparatus of this description, made with much more care, and in a more perfect manner, would be very useful for illustrating mechanical lectures, and for the instruction of students. The strains on different parts of a complicated arrangement of timber might be shown by means of it. For those portions, such as counter-braces, which sustain a strain of extension instead of compression, something like a fisherman's pocket-balance, with an adjusting screw, would answer the purpose.

A. COOKE, Brevet Major, R.E.

PAPER V.

REPORTS ON THE DEMOLITION OF THE FORT OF TUTTEAH,

By LIEUTENANT COLONEL NICHOLSON, MAJOR LENNOX, and LIEUTENANT PRITCHARD, Royal Engineers.

Letter from Major Nicholson, R.E., to Lieut. Col. H. D. Harness, Commanding Royal Engineer in India.

Camp, Cawnpore, 9th February, 1858.

Sir,

I have the honour to enclose a report on the destruction of the Rajah's Fort, at Tutteah, by Lieut. Pritchard, an accompanying letter from Lieutenant Lennox, who was in command of the party, and a plan showing the positions of the several mines. A plan of another fort named Tirowa, visited by the same force, is also enclosed.

The force under the command of Major General Windham left the main column, on its march from Cawnpore towards Futtyghur, at the camping ground of Arowl, and taking a course parallel to the Grand Trunk Road, camped first at Tutteah, and then at Tirowa; the first was in the possession of a rajah who had been committing great ravages, and had been taking the revenues of his province to himself; the second was the abode of a friendly Ranee or queen. The object of visiting Tutteah was its destruction, and of passing through Tirowa of thanking the Ranee for her kindness to some of our fugitive countrywomen.

The Commander-in-Chief accompanied the column to Tutteah, and pointed out himself what he wished to be accomplished, and as I was in attendance on him, I gave Lieut. Lennox the necessary instructions.

I beg to add that Lieut. Lennox accomplished the duty for which he was detailed in a most successful manner; and the rapidity with which all the operations were performed reflects great credit on him and on all the officers and men under his command.

For all the details I beg respectfully to refer you to the enclosures.

I have the honour to be, Sir,

Your most obedient servant,

LOTHIAN NICHOLSON, Major, R.E.

Letter from Lieut. Lennox, R.E., to Major Nicholson, R.E., Chief Engineer, Head-Quarters.

Camp, Futtyghur, 30th January, 1858.

Sir,

His Excellency the Commander-in-Chief issued the following General Order, No. 5, on the 27th December, 1857, when at Camp Arowl:—

"A Force, composed as below, will march to-morrow morning at 6 o'clock, under command of Major-General Windham, C.B., agreeably to a route that he will receive from the Chief of the Staff.

"A light field battery.

"An 8-inch howitzer of the Naval Brigade, with a double crew.

"Half of the Engineers and Sappers and Miners.

"A squadron of Irregular Cavalry.

"The 5th Brigade of Infantry, including the 4th Punjaub Infantry."

In accordance with this order, the effectives of the Engineer Brigade were divided into two (the sick, &c. remaining with the main column), and I, by your direction, proceeded in command of that part of the Engineer Force with Major-General Windham; viz.

Officers.		Names of Officers.	CORPS.	Serjeants, (English.)	Havildars.	Buglers.	Rank and File.	Total.
English	Native							
4	2	Lieut. G. D. Pritchard, R.E. " G. Swetenham. Ensign Garstin, Qr. Mastr. Assist. Surgeon J. J. Henry, 43rd Regiment. 1 Native Officer of Bengal Sappers. 1 Native Officer of Punjaub Sappers.	Royal Engineers	2	..	2	51	55
			Bengal Sappers & Miners	.	..	..	8	8
			Punjaub ditto	1	2	..	24	27
			Total	3	2	2	83	90

The Force left Arowl soon after the hour named, on the 28th December, 1857, and leaving the grand trunk road on its right, marched by a Kutcha road towards Tutteah. The crossing of the Eesun Nuddee occupied about two hours; the Engineers assisted by cutting down the banks and making ramps; the bottom of the Nuddee was a kind of quicksand.

The Force reached Tutteah about 11½ A.M. and found the fort deserted, the Rajah of Tutteah having fled, with 5000 followers, on the previous day, taking with him his five guns.

The Engineers were quartered in sheds, within the outer line of works, in order to be close to the fort, which his Excellency the Commander-in-Chief ordered to be demolished. The rest of the troops were encamped to the east of the fort.

At Tutteah, and on the march thither, the civil authorities had several disaffected men executed.

His Excellency the Commander-in-Chief (escorted by a squadron of Irregular Cavalry under Major Probyn) accompanied General Windham to Tutteah, and then proceeded across the country to join the camp of the main body of the force at Meeran-Ke-Serai, to which place they had marched by the Grand Trunk Road the same day.

A plan and a description of the Fort of Tutteah, and of its demolition (by Lieut. Pritchard, R.E.) are enclosed.

The Royal Engineers were divided into three reliefs of 16, 17, and 17 men respectively; the Punjaub pioneers, being uninstructed, were simply used as coolies: the Bengal Sappers were however employed in mining.

We commenced work at 7 P.M., on the 28th December; ten mines were begun on that night in situations selected by yourself; a Line party of 200 men was also employed in picking down the outer line of works, which was kutcha.

During the day of the 29th, 400 of the Line were employed; the ten mines were all completed and fired by the evening.

After you left Tutteah for Meeran-Ke-Serai on the evening of the 29th December, we commenced 26 mines; we were enabled to do this by getting some volunteers from the working party of 200 of the Line.

On the 30th, 400 of the Line were employed during the morning, and at 4 P.M., the 26 mines commenced the previous night, containing 2,400 lbs. of powder, were fired.

The result of the 48 hours work was the complete destruction of the outer line of works, which were picked down by the Line working parties; and of the entire demolition of the North Face, of the Zenana, of the South West Salient, and of the principal towers in the place.

We found 4,115 lbs. of powder in the fort, and used 3,875 lbs. of it in its demolition by 39 mines, without an accident, I am happy to say.

Our elephants were of great use in pulling down some of the houses and sheds about the fort.

We set fire to the ruins, and to the village below the fort, before leaving Tutteah, which the force did at 7 A.M., 31st December, 1857.

We passed through the village of Tirowa, and encamped on the far side of the Eesun Nuddee.

General Windham, with his staff, went into the fort of Tirowa as the column passed, to visit the Ranee, who is well affected towards the English, and has given protection to several of our countrywomen, for which reason she has been attacked several times by the Rajah of Tutteah.

I accompanied General Windham, and, from what I saw of the fort, I considered it advisable, for fear that it should ever fall into the enemy's hands, to send an officer back from the camp to sketch it. Lieut. G. Swetenham, R.E., performed this duty very expeditiously; his plan is enclosed; also a sketch by Lieut. Harrison, R.E., from a pencil drawing by Lieut. Oliver, R.A., which was unfortunately damaged.

On the 1st January, 1858, General Windham's force marched into the head-quarter camp at Gooreshaigung. I left the Engineers from Tutteah under Lieutenant Pritchard, R.E., there, and rejoined the head-quarters of the brigade, which had on that day marched to the Kallee Nuddee, to repair the suspension bridge there.

I have the honour to be, Sir,

Your obedient servant,

WILBRAHAM O. LENNOX,

Lieutenant R E., Commanding.

REPORT ON THE DEMOLITION OF THE FORT OF TUTTEAH, ORDERED BY THE COMMANDER-IN-CHIEF ON THE 28th DECEMBER, 1857, BY LIEUT. PRITCHARD, ROYAL ENGINEERS.

The village of Tutteah is situated on the west of the Trunk Road, distant about ten miles from the river Ganges at Arowl. Its fort is built on the south side of the village, and is constructed chiefly of earth, well mixed with water, in India termed *kutcha work.*

The fort has two lines of defences, an outer and an inner, the former having a command of 15 feet, and the latter a command of 45 feet, above the level of the ground. The outer, which is separated from the inner line by a dry ditch, varying from 20 to 40 feet in depth, and from 10 to 16 feet in width at the top, becoming narrower towards the bottom is rectangular in form, having 5 circular mud bastions, about 25 feet in diameter, connected together by mud walls, 15 feet high and 20 feet wide. There is a parapet about 3 feet high and 5 feet wide, made of mud, running completely round the fort, along the tops of the walls. (See accompanying plan)

The inner line, which somewhat resembles the outer in form, has, on the north-east side, three circular mud towers, rising almost vertically from the escarp of the ditch to a height of 30 feet. These towers are about 45 feet in diameter, and are made of solid earth. On the other three sides, there is a rampart about 20 feet high, above the top of the ditch, and on it are built, in the south-west corner, 4 circular brick towers, joined together by 4 brick walls, $3\frac{1}{2}$ feet thick, enclosing a square space, in which are various apartments, &c. On the remaining portion of the rampart houses are built, the outer walls of which are constructed $3\frac{1}{2}$ feet thick, and well loopholed; and these form the main defences on the south side of the fort.

JOURNAL.

28th December.—About 6 P.M. this day we commenced mining, and a working party of the Line, numbering about 200, was set to work to demolish the walls and bastions in the outer line of defences, commencing at bastion 2, and extending to the sally-port C. Two small mines were driven into wall A, at *a* and *a'*; two, *b* and *b'*, into the walls of tower B, from the inside; two into tower D, from the rooms *d* and *d'*; and one into tower E, from room *e*.

29th December.—By the morning of this day, the working party of the Line had succeeded in destroying the bastions and walls, having converted them into a complete ramp, as well as both sides of the sally-port C, the earth from which was thrown into the ditch, thus partially filling it.

At 9 A.M. the mines in wall A, as well as those in the walls of tower B, were loaded and tamped, the following charges having been placed in them, viz.:

In rear of wall A, 25 lbs. and 10 lbs.; the L.L.R. being respectively 3 feet and 2 ft.

Under walls of tower B, 2 charges, of 100lbs. each; the L.L.R. being in each case 4 ft.

At 9 30 A.M. these mines were fired, and they completely destroyed wall A and tower B.

At 10 A.M. 4 mines 1, 2, 3 and 4, were commenced in the wall of building F, from the top of shed G, at intervals of 7 feet; these mines were ordered to be driven 5 feet, and chambers made to the right.

During the forenoon a party of Bengal Sappers was employed in cutting half through the pillars *p*, *p'* of Zenana H, and also in making small mines in the wall at *h*, *h'*, in which charges of 20 lbs. were placed.

At 1 P.M. the mines in tower D, as well as the mine in tower E, having been driven sufficiently far, viz. *d*, *d'* to a length of 15 feet each, and *e* to a length of 14 feet, they received the following charges, to form 3-lined craters; viz.:

	lbs.	L.L.R.
Mine *d* . . .	400 . . .	11 ft. 6 in.
„ *d'* . . .	309 . . .	11 ft. 0 in.
„ *e* . . .	400 . . .	11 ft. 6 in.

At 4 P.M. these mines were tamped, and ready to fire, as also the two in the wall of Zenana H, and the four in building F, each of which had received a charge of 20 lbs.

At 4.30 P.M. the working, as well as the covering party of the Line, having been withdrawn from the fort, the above mines were simultaneously exploded at the sound of the bugle, by the undermentioned officers; viz.;

Major Nicholson; R.E. . . .	Mine *e*.
Lieut. Lennox, R.E.	„ *d'*.
Lieut. Swetenham, R.E. . .	„ *d*.
Ensign Garstin, B.N.I. . . .	„ *h* and *h'*.
Lieut. Pritchard, R.E. . . .	4 Mines in wall of building F.

The firing of these mines completely destroyed the north-east side of the fort, with the exception of part of wall K, and part of building F, one of the 4 mines, No 3, having failed, by exploding inwards, instead of outwards. Mine *h'* blew out its tamping.

During this day the working party of the Line succeeded in destroying the wall and bastion 3, on the south-west side of the fort, as well as that part of the wall on the south-east side left untouched last night.

The quantity of powder used this day was—

	lbs.
Mine *a*	25
„ *a'*	10
„ *b*	100
„ *b'*	100
„ *d*	400
„ *d'*	309
„ *e*	400
„ *h*	20
„ *h'*	20
„ 1, 2, 3, 4, each 20 lbs. , . . .	80
Total powder used, 29th December, 1857 .	1,464 lbs.

At 7 P.M. this day we again commenced mining, as follows:—

Two galleries were driven into the tower L, one from room *l*, and one from point *l'*; the former to a distance of 8 feet, and having a chamber to the right; the latter to a distance of 11 feet, and having a chamber to the left; four galleries into the building F, from the 3 rooms, O,P,Q, to a length of 5 feet 6 inches; where, in 3 of them, chambers were made to the right, and in the fourth one to the left; a seventh into the tower M, 15 feet long, at the end of which 2 small galleries were made, one to the right, 9 feet long, and one to the left 5 feet long, the first having a chamber to the right, the second one to the left; an eighth, in rear of the wall N, 10 feet through the mud, with a chamber to the left; a ninth into the same wall, 6 feet long, with a chamber to the right; and a tenth into the main wall, Y, of the Zenana H, at the point *y*, 7 feet long, with a chamber to the left.

The working party of the Line this night destroyed the wall on the south-western side of the fort as far as bastion 4.

30*th December*.—Early in the morning of this day several small mines were commenced, viz.—Two in the walls of tower R, at *r*, *r'*, from the inside, below the level of the ground; two in wall S at *s*, *s'*, below its foundation; and one in tower T, from the outside, at a point *t*, 5 feet beneath the floor inside, which was 7 feet higher than the ground on the outside. There were 2 chambers in this mine, right and left of the gallery, just in rear of the wall. Another mine *k* was commenced in that part of wall, K, left standing yesterday: when it had penetrated through the wall, two chambers were made, one to the right, and one to the left; two more mines were made in wall Y of the Zenana, H, out of the staircase at *y'* and *y''*, which we tamped up entirely.

Besides the above mines, we placed a charge of 100 lbs. in a hole, Z, in the corner of the Zenana H, and covered it well with earth.

Mine 3 in building F, which failed yesterday, had 2 more chambers cut, right and left of the old gallery, each of which received a charge of 30 lbs.

The mine *h'*, which blew out its tamping, was driven further in, and another mine *h''* was made, to its left, in the same wall.

By 10 A.M. all the mines commenced last night were ready for their charges, which were as follows—

	lbs.	L.L.R.
Mine *l* . . .	150 . . .	7′ 6″
„ *l'* . . .	350 . . .	11′ 0″
4 mines in building F	200 . . .	5′ 6″
Mine *m* . . .	400 . . .	11′ 6″
„ *m'* . . .	300 . . .	10′ 0″
„ *n* . . .	80 . . .	3′ 0″
„ *n'* . . .	100 . . .	6′ 0″
„ *y* . . .	70 . . .	5′ 0″
Total........	1,650 lbs.	

These mines were tamped at 4 P.M.

The mines commenced this day were charged at 12′ 30″ P.M., as follows:—

	lbs.	L.L.R. ft.	in.
Mine *r*	100 . . .	4	0
„ *r'*	100 . . .	4	0
„ *s*	60 . . .	2	0
„ *s'*	60 . . .	2	0
„ *t*	35 . . .	4	0
„ *t'*	35 . . .	4	0
„ *k*	30 . . .	3	0
„ *k'*	30 . . .	3	0
„ *y'*	40 . . .	3	6
„ *y''*	40 . . .	3	6
„ *z*	100 . . .	5	0
„ 3 (2 chambers) . .	60 . . .	5	0
„ *h'*	30 . . .	1	6
„ *h''*	30 . . .	1	6
Total .	750 lbs.		

and these were tamped by 3 p.m.

By 4.30 P.M. all the hose having been laid and the portfires attached, as shewn in plan, the mines were fired simultaneously, at the sound of the bugle, by the under-mentioned officers, viz.

Major Nicholson, R.E. . .	Mines *s*, *s'*.
Lieutenant Lennox, R.E. . .	*m*, *m'*, *n*, *n'*, *y'*, *y''*, *z*, *y*, *h'*, *h''*. 4 mines in buildings F and *l*.
Lieut. Wynne, R.E. . . .	*r*, *r'*.
Lieutenant Swetenham, R.E. .	*t*, *t'*.
Ensign Garstin, B.N.I. . .	*k*, *k'*.
Dr. Henry, Staff Assistant Surgeon, No. 3, (two charges.)	
Lieut. Pritchard, R.E. . .	*l'*.

The working party of the Line this day demolished the bastions 4 and 5, and the wall between them, which completed the destruction of the outer line of defences.

Calculation of Charges.

In the mines in towers B, R and T, in rear of walls, A, N, S and K, and in the three mines, *h*, *h'*, *h''*, in wall of Zenana H, as well as in mine *z*, we did not care how much over the prescribed quantity of powder we used, because we wished to shake the buildings attached, and besides, the powder itself having been found in the fort, and being of native manufacture, we did not know what were its explosive powers.

Mines *d*, *m*, and *e*, having a line of least resistance of 11′ 6″ each, and wishing to form 3-lined craters, we calculated the charges thus:—

$$\text{As } \left(\frac{\text{L.L.R.}}{4}\right)^3 = \text{charge in lbs.}$$

$$\therefore \left(\frac{23}{2}\right)^3 \times \tfrac{1}{4} = \text{charge in lbs.}$$

$$\therefore \text{ Charge in lbs.} = \frac{12167}{32} = 380\frac{7}{32},$$

but we placed a charge of 400 lbs. in each of them.

Mines *d'* and *l'*, lines of least resistance 11 feet, were to form 3-lined craters.

$$\text{As charge in lbs.} = \left(\frac{\text{L.L.R.}}{4}\right)^3$$

$$\therefore \text{ Charge in lbs} = \left(\frac{11}{4}\right)^3 = \frac{1331}{4} = 332\tfrac{3}{4}.$$

In these mines we placed charges of 309 lbs. and 350 lbs. respectively, *d'* having 309 lbs. instead of 332¾ lbs., by a mistake of the Sapper, who neglected to put in the whole charge, although it was by his side.

Mine *l*, line of least resistance 7 ft. 6 in., intended to form 3-lined crater,

$$\therefore \text{ Charge in lbs.} = \left(\frac{15}{2}\right)^3 \times \tfrac{1}{4} = \frac{3375}{32} = 105\frac{15}{32},$$

but in mine *l* a charge of 150 lbs. was placed.

Mine *m'*, L.L.R.=10′ 0″, intended to form 3-lined crater,

$$\therefore \text{ Charge} = \frac{10^3}{4} = \frac{1000}{4} = 250 \text{ lbs.}$$

but mine *m'* received a charge of 300 lbs.

The four mines 1, 2, 3, 4, in building F, L.L.R. = 5′ 0″, were to form 3-lined craters.

As charge in lbs. $= \text{L.L.R.}^3 \times \frac{3}{20}$ (without counterforts),

$$\therefore \text{Charge} = 5^3 \times \frac{3}{20} = \frac{375}{20} = 18\tfrac{3}{4} \text{ lbs.}$$

and each of these mines received a charge of 20 lbs.

The four mines in building F, driven out of rooms O, P, Q, L.L.R. = 5′ 6″, were intended to form 3-lined craters.

As charge in lbs. $= \text{L.L.R.}^3 \times \frac{2}{10}$ (with counterforts),

$$\therefore \text{Charge} = \left(\frac{11}{2}\right) \times \frac{2}{10} = \frac{1331}{40} = 33\,\frac{11}{40} \text{ lbs.},$$

but these mines received charges of 50 lbs.

Mine *y*, L.L.R. = 5 feet, intended to form a 2-lined crater:—

The charge in lbs. $= \frac{\text{L.L.R}^3}{3}$ in centre of masonry, $= \frac{5^3}{3} = \frac{125}{3} = 41\,\frac{2}{3}$,

but this mine received a charge of 70 lbs.

The powder being of native production, and far less powerful than our own powder, we increased our charges considerably, as will be seen by the above calculations.

Powder used on 29th December, 1857 .	1,464 lbs.
" 30th " .	1,650 "
" 30th " .	750 "
Quantity of powder used in demolition.	3,864 "

The towers D, E, L, and M were destroyed thoroughly, but we were not so successful with towers R and T. The building F was well demolished, as also the Zenana, H, and the wall N.

We left off work at 7 P.M. on the 30th December, 1857, and set fire to everything that would burn in the fort; and thus ended the demolition.

(Signed) G. D. PRITCHARD, Lieut., R.E.

PAPER VI.

Description of the Floating Stage at the Landing Steps of Rochester Bridge, Constructed by John Wright, Esq., C.E.

The stage above-named has been in use at Rochester bridge for upwards of two years, and has been found to answer the purpose exceedingly well. It would be found most useful in front of dockyards and public landing places (where boats are frequently left waiting for their crews whilst the latter are engaged on shore), for they require no boat-keeper to attend to them as the tide rises and falls, and the stage is also more convenient to step on or off, when entering or leaving a boat, than a flight of steps, as now generally in use.

The stage consists of an iron caisson (see Plan), thirty feet in length and twelve in breadth, floating in front of a flight of steps, and always close to them, whatever may be the state of the tide, rising and falling at the same inclination as the steps, which is simply effected by means of a chase or groove in the masonry at each end of the stage, in which cast-iron wheels, fixed to the stage, move up and down with it; and, as the chase is inclined, the stage is forced to rise and fall in the same sloping direction, advancing outwards as it descends, and towards the shore as it rises. Two wheels are also fixed to the inside of the stage, working on an inclined plane, corresponding with the chase, which keeps the stage always horizontal and steady when unequally weighted by persons or goods. A small quantity of oil applied to the wheels occasionally is all the attention which it requires, and it is never likely to get out of order.

It is thought that if this system, on a large scale, were adopted for the landing stages on each side of the Thames and other rivers, instead of the unsightly projecting piers and floating barges at present in use for steam-boats, a great improvement might be effected, as the stages then, by receding towards the shore with the flow of the tide, would relieve the river of the great obstructions now offered, and would render all the large space, at present quite useless for the passage of vessels, open and free to the navigator, whilst the landings themselves would be more convenient and more easily approached than by the lines of unsteady barges and steep inclines, as at present.

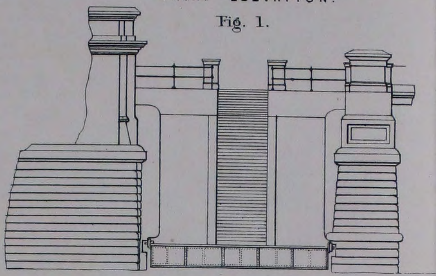
J. W.

SKETCH OF LANDING

CONSTRUCTE

FRONT ELEVATION.

Fig. 1.



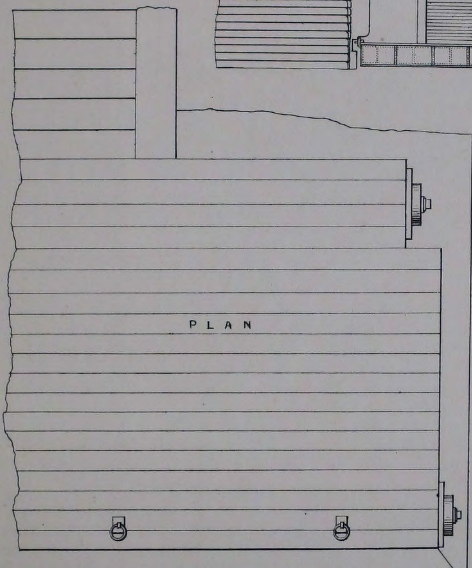
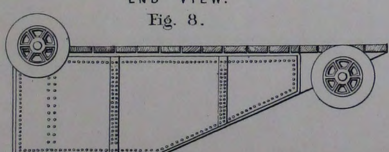


Fig. 4.

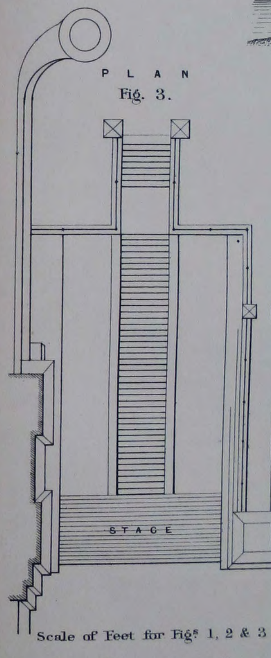
END VIEW.

Fig. 8.



PLAN

Fig. 3.



Scale of Feet for Figs 1, 2 & 3

10 0 10 20 30 40 50

Scale of Feet for Figs 4 to 8.

1 0 5 10

PAPER VII.

Report on the Demolition of a Portion of the Old Bridge at Rochester, by the Royal and East India Engineers, in 1857, Conducted by Capt. W. H. Noble, R.E., under Col. Sandham's Directions.

The mining operations for the demolition of the old bridge at Rochester, carried on in 1856-57 by the Royal and East India Engineers, under Captain Schaw, R.E., the account of which was published in the 7th Volume of the Royal Engineer Professional Papers, were resumed on the 14th July, 1857, and were continued till the 25th Sept., 1857, by Captain W. H. Noble, Royal Engineers, under Colonel Sandham's direction.

The permission of the Trustees of the bridge for carrying on these mining operations was granted, with the understanding that their resident engineer, John Wright, Esq., under whose superintendence the new bridge was built, should be made aware of the disposition of every charge, and that his consent to their being fired should be obtained. Throughout the operations Mr. Wright afforded every assistance in his power, and on many occasions made very valuable suggestions, which were taken advantage of.

Mr. John Foard, the contractor for the removal of the old bridge, also in every instance furthered, as far as lay in his power, the object of giving mining instruction to the Corps, which Colonel Sandham had in view.

The Abutment at the Rochester end of the bridge, the Arches Nos. 1, 2, 3, and 4, and the Piers, Nos. I, II, and III, (see general plan) were attacked separately.

Two $1\frac{1}{2}$-inch jumper holes (*a*, *a′*), 4′ 6″ deep, were sunk in one of the voussoirs of the west haunch of the upper added portion of No. 1 Arch* (l.l.r. 1′ 6″, to the soffit of the arch). One of the holes only was loaded with 1 lb. 2 ozs. of powder ($\frac{1}{3}$ l.l.r.^{3}) and fired by Bickford's fuze on the 17th July, 1857. The voussoir in which the charge was lodged was split and blown out towards the face of the arch, and all the voussoirs were more or less lifted from their beds, but they sank back into their places, clasped a part of the stone in which the charge was exploded, before it could fall from its place, and the arch resumed its form.

2nd. On the 18th of July one $1\frac{1}{2}$-inch hole and one 3-inch hole (*b*, *b′*,) were sunk in the two voussoirs immediately above the one split on the 17th (l l.r. 1′ 6″ to the soffit of the arch) and charged with 1 lb. 8 ozs. ($\frac{4}{9}$ l.l.r. ^{3}), and were fired by the Voltaic battery on the 19th July. The two voussoirs were broken and displaced, but portions of them, about 15 inches thick, remained attached to the original arch by iron clamps, which was sufficient to keep the arch from falling, though it was quite disjointed.

* The construction of these arches was peculiar, and is shown in the elevation. The bridge is described in page 2 of the 7th Volume of this Series as having been originally formed of arches only $16\frac{1}{2}$ feet wide, to which were *added* subsequently segmental arches of cut stone, 6 feet in width, on either side of each arch.—Ed.

3rd. Two jumper holes (*c*, *c*) were sunk in the left haunch (looking down stream) of the lower added portion of No. 1 Arch, similar to those that had been fired in the upper added portion, and were loaded with 1 lb. 10 ozs. ($\frac{13}{27}$ l.l r.^{3}) in each, (l.l.r. 1 ft. 6 in. to the soffit of the arch). The key-stone had been removed, as an experiment, to see whether the arch would fall on its being removed, but the added portion being clamped to the original bridge, it did not fall. The two charges were to have been fired simultaneously by the Voltaic battery, but one only exploded, and it brought down the whole arch with violent effect.

As the upper added portion still retained the arch shape, though much shaken, it afforded another opportunity for experiment. The haunch next Rochester (the right), owing to its being curved to run into the wing wall of the Abutment, was broad enough to admit of four 3-inch holes (*d*, *d*, *d*, *d*,) being bored into the course of voussoirs next the springing, and three (*e*, *e*, *e*,) into the next above it, the holes being checkered, and sunk so as to leave l.l.r. 9 in. only. The holes were loaded with 6 ozs. of powder ($\frac{8}{9}$ l.l.r.^{3}) each, and were fired simultaneously by the Voltaic battery on the 21st July, 1857, by Captain Scott, R.E. The demolition was complete, but rather too violent, probably owing to the dislocated state of all the voussoirs.

After the above experiments No. 1 Arch of the *original* bridge stood divested of the portions that had been added to each side to increase its width. It was 16 feet 8 inches wide, built of rubble masonry supported by 5 ribs of cut Kentish rag stone under the soffit, and the span was 18 feet. Two rows of 3-inch holes, one of four (*f*, *f*, *f*, *f*) in line with the face of the Pier No. 1, and the other of three (*g*, *g*, *g*) checkered with them, were sunk from the top of the arch, 2′ 6″ apart. giving l.l.r. 1′ 3″ to the soffit, and were loaded with 15¾ ozs. of powder ($\frac{1}{2}$ l.l.r.^{3}) in each hole. They were fired by the Voltaic battery on the 1st of August, and all but one exploded simultaneously. The whole of the voussoirs of the haunch were dislocated, and one was broken to pieces, but the arch did not come down. The charge that failed was afterwards exploded, but produced no effect.

Two rows of 3-in. holes, one of 6 (*i*, *i*, *i*, *i*, *i*, *i*), and the other of 5 (*h*, *h*, *h*, *h*, *h*) checkered, were sunk in the voussoirs on each side of the key stone at equal distances, making the l.l.r. 10 in. to the soffit of the arch. Each hole was loaded with 1 lb. of powder (1·7 l.l.r.^{3}) and all were fired simultaneously by the Voltaic battery on the 11th August, 1857; the charges were connected with the wires, as shewn in Fig. 3, by Captain Scott, and this arrangement was adopted by him in all cases. Although the effect was violent, the passage over the arch was not entirely interrupted: a portion of it was held up by a fragment of one voussoir, which was removed by a crow bar, and the arch then fell in fragments on the starling, which extended across the whole span; not a stone fell into the river.

The above experiments proved that the demolition of an entire arch cannot be effected by following the rules laid down for destroying an ordinary wall. In the case where violent demolition took place with one explosion only of 1 lb. 10 ozs. of powder (3rd experiment), the key-stone of the arch having been removed before-hand, the arch was in the condition of a simple wall.

A stage of baulks was now securely fixed from starling to starling, beneath Arch No. 2, which was next to be attacked. In the upper added portion of the arch, one 3-inch jumper hole (*k*) was bored 8 ft. 10 in. deep from the top of the bridge, into the 3rd voussoir from the springing on the left side of the arch, so as to produce two equal l.l.r.s of 2′ 6″, one to the soffit and one to the face of the arch; it was loaded with 4 lbs. 11 ozs., or $\frac{3}{10}$ l.l.r.^{3}, being an increase of 3 lbs. 9 oz. on the quantity used in a similar manner in Arch No. 1. The charge was fired on the 21st August, 1857; the arch was much cracked, but it did not fall; it was however easily thrown down by crowbars. A hole (*l*), precisely in the same position in the lower added portion, was now loaded with 6 lbs. This charge was fired, but the arch was not brought down by it. In both these last cases the filling in of the spandrils, which could scarcely be called rubble masonry, was blown out, and the cutwaters of the pier were much disturbed.

These experiments also showed the strength and tenacity of the arch form, and that it requires a greater charge, or other arrangements than the one simple set of charges that would be applied to a wall, to bring it down.

The lower added portion of No. 2 Arch not having been much disturbed by the explosion of 6 lbs. of powder in one hole in the left haunch, three holes (*mmm*) were bored 2′ 3″ deep into the voussoirs of the right haunch, which were bare, (the spandrils having been previously removed) giving an l.l.r. of 9 inches towards the soffit, and were charged with 1 lb. 12 oz. or $4 \times$ l.l.r.^{3} in each; and one hole (*n*) 1 ft. 3 in. deep in the key-stone (which had also no covering to it), was charged with 1 lb. of powder ($2\frac{1}{6}$ l.l.r.^{3}). These charges were fired simultaneously and produced complete demolition of the arch, the key-stone being violently projected into the air.

No. 2 Arch of the original bridge having been freed from the upper and lower added portions, seven 3 inch holes, which had already been sunk in the voussoirs of the west haunch, in two rows across the bridge, four (*o, o, o, o*) in line with the face of the pier 8′ 10″ deep, and three (*p, p, p*) 7′ 6″ deep, 2′ 6″ in advance, checkered with them, each having an l.l.r. of 2′ 6″ to the soffit, were deepened 4 in. in consequence of the failures in the added portions, thus reducing the l.l.r. to 2′ 2″ towards the soffit of the arch. These were loaded with 5 lbs. 4 ozs. ($\frac{1}{2}$ l.l.r.^{3}) in each hole, and the charges exploded simultaneously. The effect was solely to throw up the filling in of the spandril, which was formed of rubbish almost without mortar, and the arch was not at all disturbed—this again proved the tenacity of the arch form.

In No. 2 Arch, two rows of holes were also sunk in the voussoirs of the right haunch, one row of 5 holes (*q, q, q, q, q*) being 2′ 6″ in front of the face of the pier, and the other of 4 (*r, r, r, r*), checkered, each having an l.l.r. of 1′ 6″ towards the soffit of the arch, and were loaded with 4 lbs. of powder each ($1\frac{2}{10}$ l.l.r.^{3}); and two rows of holes in the voussoirs on each side of the key-stone, one of 5 (*s, s, s, s, s*) and the other of 4 holes, (*t, t, t, t*) checkered, each having an l.l.r. of 9 inches to the soffit of the arch, were loaded with 1 lb. of powder in each hole, or $2\frac{1}{6}$ l.l.r.^{3}. All these charges were fired simultaneously by the Voltaic battery, on the 26th August 1857, at high water; the demolition was complete, and the stage received all the debris—not a stone fell into the river.

No. 3 Arch was attacked in the following manner—the upper and lower added portions had two holes (*u, u*) bored in each haunch, one about 3 feet in advance of the other, the l.l.r. being 1 ft 6 in., and were charged with 4 lbs. of powder, or $1\frac{2}{10}$ l.l.r.^{3}, and one hole (*v, v′*) in each voussoir, next the key-stone, with l.l.r. 9 in. to the soffit of the arch, were charged with 1 lb. in each hole, ($2\frac{1}{6}$ l.l.r.^{3}). Nine $3\frac{1}{2}$-in. holes, in two rows, checkered, were bored into the voussoirs of the left haunch of the original arch, a row of 5 (*w, w, w, w, w*), being 1 ft. in front of the face of the pier, and a row of 4 (*x, x, x, x*) checkered with them, 2′ 6″ in front of them, with l.l.r. 1′ 6″ to the soffit of the arch, and each hole was loaded with 4 lbs. (or $1\frac{2}{10}$ l.l.r.^{3}). Two rows of similar holes were also bored into the voussoirs next the key-stone, 5 (*y, y, y, y, y*) in one row, and 4 (*z, z, z, z*) in the other, checkered, the l.l.r. being 9 inches to the soffit of the arch, and each hole was loaded with 1 lb. of powder, or $2\frac{1}{6}$ l.l.r.^{3}.

In the added portions of No. 4 Arch, both above and below, one hole in each haunch, having an l.l.r. of 1′ 6″ to the soffit, and two holes in the voussoirs on each side of the key-stone, with l.l.r. 9 inches, were prepared and loaded with 4 lbs. and 1 lb. of powder each respectively. In the crown of the original arch 11 holes were sunk in the voussoirs next the key-stone, 6 in one row and 5 in the other, checkered (see plan); they each had an l.l.r. of 9 in., and were loaded with 1 lb. of powder each. This was an experiment to ascertain whether charges so arranged in the crown of the arch, and discharged simultaneously, would throw down the arch, and to what extent, previous to destroying No. III Pier, which of course would bring down with it whatever of the arch might remain.

It was now decided to complete the demolition, to the extent of the 3rd and 4th arches, and Piers I, II, and III, by a series of explosions on the 22nd of September, 1857, at spring tide.

Should the experimental charges in the crown of No. 4 Arch not bring down the arch, which was considered very doubtful, the arch was to be destroyed by the demolition of No. III Pier, which would inevitably bring the arch down with it.

During these operations shafts and galleries were worked in the Abutment and in the Piers of the bridge. Two shafts were injudiciously sunk in the earth at the back of the masonry of the Abutment; water percolated into them, and, as the tide rose, it was necessary to use pumps. The work would have been executed in a shorter time, by fewer men and with much less labour, had the shafts been sunk in the masonry.

Shafts were sunk at the same time from the central points of the tops of Nos. I, III, IV, and VII Piers, and a gallery was driven into No. II Pier from the level of the starlings, or about 8 or 9 feet above low water mark.

The Table attached to this Report shows the progress of work in shafts and galleries, with other information.

The shafts and galleries, and the chambers, in the Abutment and in Nos. I, II, III, and IV Piers, are shown in the plan, and were finished, and ready to receive their charges, by the 6th August, 1857. In the Abutment three chambers at two-lined intervals were so arranged that each l.l.r. should be 7′ 6″, the outside charges having each two equal l.l.r.s, one towards the face of the wing wall and the other towards the face of the Abutment, whilst the l.l.r. of the central charge was in the direction of the face of the Abutment (see plan).

The contractor expressed a wish to have the joints of the masonry of the Abutment and wing walls, which were of cut stone, only dislocated, that the stones which were valuable might be removed by crowbars: the charges were accordingly calculated at $\frac{1}{10}$ l.l.r.^{3} or 42 lbs.; they were prepared for damp soil, in tin cases, which had loading holes; and two small tin cylinders, closed at one end, were fixed so as to project into each case, to receive two sets of priming wires, lest one might fail; connecting wires, sufficiently long to reach to the tops of the shafts, were attached to the priming wires before the charges were placed, each being distinctly ticketed, that no mistake in connecting them with the battery might afterwards be made; and they were carefully cased before the tamping was commenced. The tamping, which was carried to the tops of the shafts, was chiefly of river clay, retained in its place by dry walls of stone, built in the galleries at intervals of five or six feet.

Everything being arranged and completed by the 22nd of September, 1857, the charges in the Abutment were fired by the Voltaic battery, and although two only exploded, (for the outside charge on the down-stream side was not ignited), the effect was so nearly what was desired, that one blast hole, in the neighbourhood of the charge that failed, was all that was necessary to enable the labourers to remove every stone by hand.

The following explosions, by means of the Voltaic battery, in charge of Capt. Scott, also took place; 1st, the charges in the lower added portion of No. 4 Arch were fired, viz.: —one in a voussoir of each haunch of 4 lbs. (l.l.r. 1′ 6″ towards the soffit) and two in the two voussoirs next the key stone, of 1 lb. (l.l.r. 9 in. towards the soffit) which produced a perfect effect.

2nd. A charge of 30 lbs., suspended under the soffit of the key-stone of the south added portion of No. 4 Arch, was exploded, which split the key-stone without displacing it; and it was then thrown down in the same manner as the lower added portion of No. 4 Arch, holes having been previously prepared, to be available in case of the anticipated failure of the charge of 30 lbs.

3rd. The upper and lower added portions of No. 3 Arch were next thrown down, the charges being the same in every respect as those placed and fired in the added portions of No. 4 Arch, and the effects were perfect.

4th. The added portions of No. 3 Arch having been thrown down, the 9 charges in the left haunch of the original arch, each having an l.l.r. of 1′ 6″ towards the soffit, and being loaded with 4 lbs. ($1\frac{1}{8}$ l.l.r.^{3}) in each, and the 9 charges similarly disposed in the voussoirs adjoining the key-stone (having each an l.l.r. of 9 inches and charge of 1 lb.) were fired simultaneously, and produced perfect demolition without violence.

5th. It was intended that Pier III, in which two charges of 200 lbs. (or $\frac{3}{20}$ l.l.r.^{3}) were placed, each charge having four equal l.l.r.s of 11 ft., should be thrown down, and that Arch No. 4, losing its support, should fall with it, but the contractor objected, as he feared that the total mass of the arch and pier, falling at once on the stage beneath, would break it, and that the whole mass would thus fall into the river; he also feared that the sudden disruption of the pier and arch on which Arch No. 5 rested might cause it to fall away, and that a kind of "Jack after yeast" would take place with all the other arches. As he would not consent to the experiment in this shape, two rows of blast-holes, one row in each voussoir, next to the key-stone of No. 4 Arch, were hastily bored, and loaded with charges of 1 lb. each, which were exploded, time not admitting of holes being bored in either of the haunches; this however was an interesting experiment, it broke through the arch and blew away the key-stones in four places; yet it did not bring down the arch. Complete demolition might have been effected by surcharging each hole, but it was not thought safe so to treat them, for fear of projecting splinters amongst the spectators. After this failure the contractor consented to the charges in Pier III being exploded, and the effect was perfect: not a stone was thrown a yard from its original bed, but the whole pier and No. 4 Arch attached to it, as far as the key-stone displaced by the explosion above described, crumbled and fell on to the stage below. Three or four of the outside timbers were forced away, and a few stones found their way into the river. This explosion, with the previous one of the blast holes in the crown of Arch No. 4, produced visible cracks in No. 5 Arch, but not a stone of it was displaced.

6th. Two charges of 200 lbs. each ($\frac{3}{20}$ l.l.r.^{3}), having four equal l.l.r.s of 11 ft., were placed in chambers at the end of horizontal galleries in Pier II, and they were exploded simultaneously by the Voltaic battery. The demolition was perfect, and not violent. In this case the galleries were tamped with sandbags filled with river clay.

7th. Two chambers in Pier I, having each four equal l.l.r.s of 11 feet, were loaded with 133 lbs. each, or $\frac{1}{10}$ l.l.r.^{3}, and tamped with river clay; and walls of dry stones were built in the gallery at intervals. The charges were exploded simultaneously by the Voltaic battery, and produced perfect demolition; indeed the masonry was broken up quite as much by these charges as by larger ones of $\frac{3}{20}$ l.l.r.^{3}.

After these explosions the mining operations were suspended until the debris caused by them could be removed, and to allow of the erection of a tramway of the entire breadth of the bridge, formed upon large square baulks of deal timber supported by others trussed outside, and leaving the space between them free. On the tramway thus formed two travellers with travelling cranes were mounted, one of multiplied power, to lift the heaviest weights and to draw the piles of the foundation, and the other for the general object of lifting the materials into barges.

The following Regimental Order was issued on the 24th September, 1857 :—

"No. 1. The mining operations at Rochester bridge will be discontinued for the present, and all tools, stores, &c., will be brought into store to-morrow.

"No. 2. The Commanding Officer has witnessed with great satisfaction the zeal and intelligence with which the instructive operations and experiments in mining, in the masonry of old Rochester bridge, have been carried on by the officers, non-commissioned officers, and sappers employed. The operations have extended over 10 weeks, during which period 491 non-commissioned officers and sappers have been employed in them, and only two cases of irregularity have occurred. The manner in which the whole of the operations have been conducted reflects the highest credit upon every one engaged in them, and tends to add to the high character the Corps has invariably earned for itself whenever employed on distinct duties and operations.

"The Commanding Officer more especially expresses his thanks to Captain Scott, Captain Noble, Lieutenant Mainguy, Lieutenant Durnford, and Serjeants Mitchell, Lockwood, and Wilmore, for their unremitting attention, which has brought the present operations to a close without a single accident."

Remarks.

The experiments show that an arch cannot be treated as a simple wall; it must be destroyed by a combination of charges, or by a surcharge. In the position of this bridge surcharges could not have been used without danger, or infringing one of the stipulations under which the mining experiments were permitted to be carried out, viz. that no stone was to be projected into the river; and this stipulation would have been complied with, almost to the letter, had not a portion of one of the stages beneath the arches, to receive the debris, given way (in one place only). By the demolition of the arches the conclusion arrived at is that the most certain way to attack them is to apply two rows of blast holes, checkered with each other, at two lined intervals, at a haunch and at the crown, in both cases boring into the voussoirs and loading more heavily at the haunch than at the crown, and to explode them simultaneously. In regard to the demolition of the Piers and Abutments, the effect produced by charges of $\frac{1}{10}$ l.l.r.^{3} were equally satisfactory with those produced by charges of $\frac{3}{20}$ l.l.r.^{3}; in both cases they were all that could be desired, considering the circumstances and restrictions under which the operations were carried on.

In boring or jumping 3-inch holes, the progress averaged 6 inches per hour to the depth of about 4 feet; beyond that depth it averaged not more than 2 inches per hour. The borer or jumper often got jammed in the joints of the rubble masonry, and in some cases not more than 1 inch an hour was bored in the deeper holes. 5 feet of tamping per hour was executed, the material (broken brick or chalk) being on the spot.

The shafts (4′ 6″ × 4′ 6″) were sunk in the masonry at an average rate of 2½″ per hour, but the progress in driving a gallery of the above dimensions into the masonry averaged only 1 inch per hour.

The charges for the piers and abutments were prepared to resist water, under the directions of Quarter-master Bradford, R E; and ten oil cans were used. 2 small cylinders for the bursting charge and primers were let into the bottom of each can as a precaution, lest one should fail, and a loading hole was also made in the bottom of the can, into which a very short cylinder of tin was introduced and soldered; this short cylinder had a rim on the inner surface of the end inside the can, so that, after the latter was loaded, a circular piece of tin could be dropped into it, to form a bottom to it, on which moist clay, (used to protect the powder from the heat of the soldering iron, in soldering on the cap after the can was filled with powder), would rest.

The can being loaded, and the bursting powder, priming holes and loading hole, being securely soldered up, the can was put into a waterproof canvas bag, which was sewed over it; the points at which the priming wires passed through the canvas being carefully closed by thrapping and additional waterproof composition. The can, thus prepared, was put into a square deal box, well coated inside and out with pitch, and the vacant space was filled with sawdust; the priming wires were then passed through holes in the lid to receive them, the lid was screwed down and the wires were secured to the outside of the lid by copper staples, to preserve them from any strain that might affect the platinum wire which connected them.

It had always been intended that the central arch, which is entirely of valuable Bramley-fall stones of large dimensions, should be removed by manual labour; it was built to span the space occupied by the two original central arches, has a span of 80 feet, with a rise of 20 feet, and springs from points 1 foot 10 inches above the level of the starlings. It was projected and built by Sir John Rennie fifty or sixty years ago, to improve the water-way; for the number of piers (9), each supported by broad starlings, had seriously affected the bed of the river by the impediment they offered to the flow and ebb of the tide. Until the tram-way and the centering under the arch were fixed, further mining experiments were suspended.

Up to this period nearly 700 non-commissioned officers and Sappers have been employed in the above operations, and during the whole time during which they have been employed only two men have been confined for irregularity.

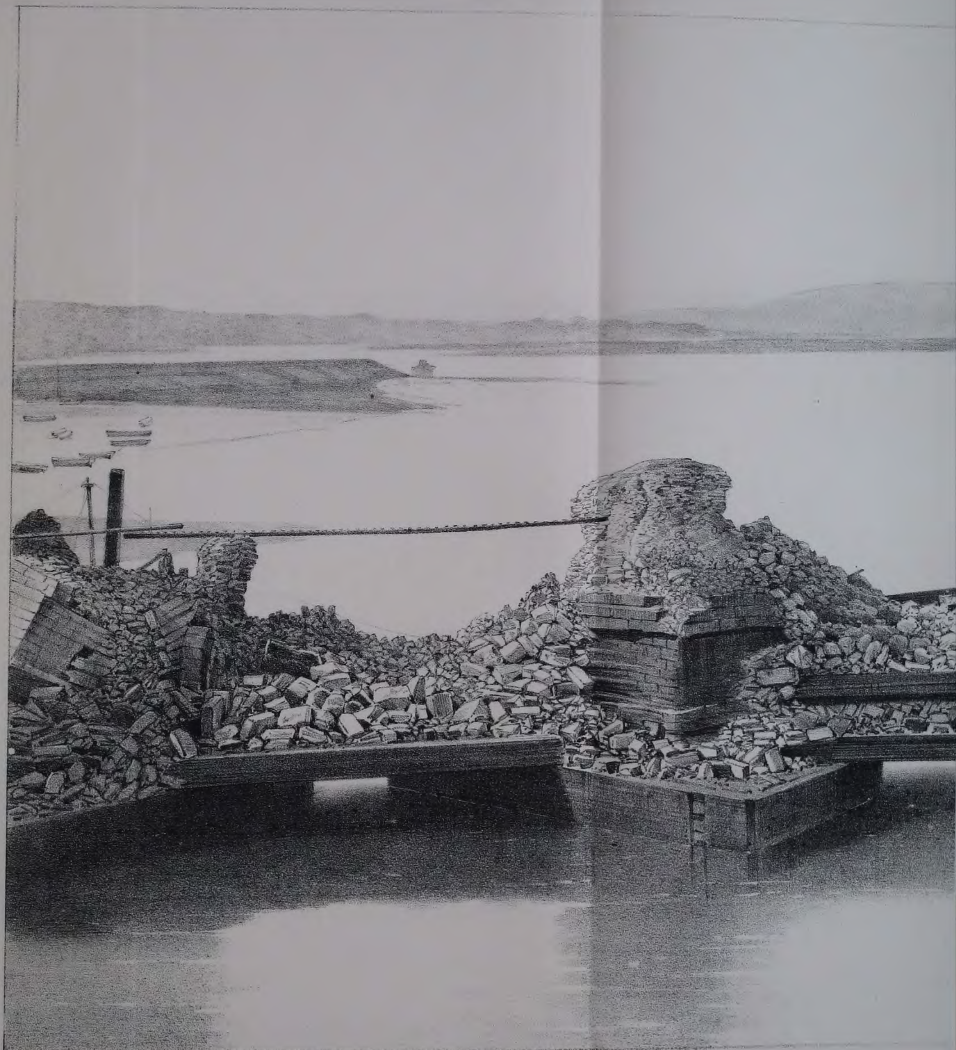
H. SANDHAM, Colonel, Royal Engineers, Director.

TABULAR STATEMENT OF THE PROGRESS OF WORKS AT THE OLD BRIDGE AT ROCHESTER, IN 1857.

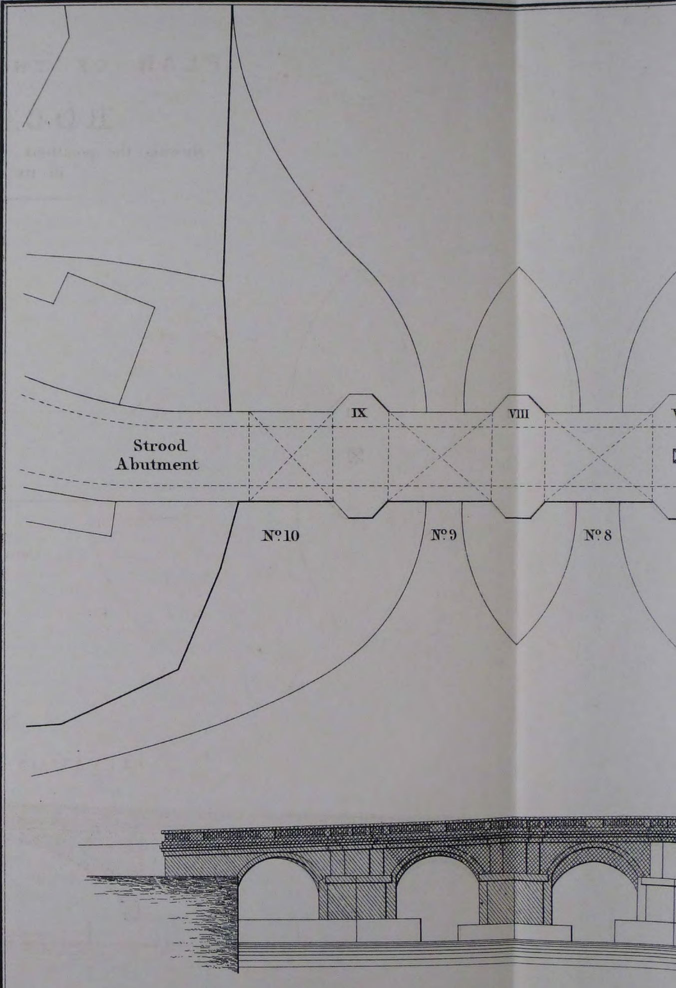
Positions of Shafts.	Gallery.	Date. Commenced.	Date. Completed.	No. of days' work.	Length of Shaft or Gallery. Feet	Rate per day. Inches.	Rate per hour. Inches.	Oz. of Powder per 1 inch of work.
No. I Pier	-	13th July	28th Aug.	13½	20⅓	18	2·25	·6
No. III do.	-	22nd -	27th -	21	25	14·3	1·80	·95
No. IV do.	-	30th -	9th Sept.	24½	24	11·76	1·46	·84
No. VII do.	-	7th Aug	31st Aug.	15½	23	17·8	2·225	·56
No. I do.	Right	29th July	6th -	7	5¾	8·43	1·05	·62
	Left	7th Aug.	12th -	4½	5	13·33	1·66	·63
No. III do.	Right	28th -	7th Sept.	8	5½	8·25	1·03	66
	Left	8th Sept.	18th -	7¾	5	7·742	·97	·83
No. IV do.	Right	12th -	18th -	5¼	2¾	6·300	·79	1·42
	Left	15th -	19th -	4¼	2½	7·06	·8	1·03
No. VII do.	Right	1st -	14th -	9	4½	6·00	·75	·54
	Left	12th -	12th -	¾	½	9·00	1·125	4·00

ABSTRACT OF CHARGES.

Date.	No. of Arch.	Position of Charge.	Charges. No.	Charges. proptn. to L.L.R.³	Charges. each. lbs.	Charges. each. oz.	Line of least resistance. ′	Line of least resistance. ″	Means of Firing.	Nature of Tamping.	Effect of Firing	Effect of Explosion.
17th July.	No. 1, upper added	Haunch, Strood side	1	$\frac{1}{3}$	1	2	1	6	Bickford's fuze.	Bricks.	Charge exploded	Failure.
18th July.	Do. do.	Ditto	2	$\frac{4}{9}$	1	8	1	6	Voltaic battery	Ditto	Do. do.	Ditto
"	Do. lower do.	Ditto	2	$\frac{13}{27}$	1	10	1	6	Ditto	Ditto	1 charge failed.	Complete, violent.
21st July.	Do. upper do.	Do., Rochester side	7	$\frac{8}{9}$		6		9	Ditto	Ditto	Do. do.	Do. rather violent.
1st Aug.	No. 1, main arch	Do., Strood side	7	$\frac{1}{2}$	1	0	1	3	Ditto	Ditto	1 charge failed.	Failure.
11th Aug.	Do. do.	Crown	11	1·7	1	0		10	Ditto	Ditto	All exploded.	Not quite successful.
21st Aug.	No. 2, upper added	Haunch, Strood side	1	$\frac{3}{10}$	4	11	2	6	Ditto	Ditto	Charge exploded	Failure.
"	Do. lower do.	Do. do.	1	$\frac{5}{13}$	6	0	2	6	Ditto	Ditto	All exploded.	Ditto
22nd Aug.	Do. do.	Do., Rochester side	3	4	1	12		9	Ditto	Ditto	Ditto	Complete but violent.
"	Do. do.	Key-stone	1	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	Ditto	Ditto
22nd Aug.	No. 2, main	Haunch, Strood side	7	$\frac{1}{2}$	5	4	2	2	Ditto	Sand and bricks	Ditto	Failure.
26th Aug.	No. 2, main	Do., Rochester side	9	$1\frac{2}{10}$	4	0	1	6	Ditto	Ditto	Ditto	Complete, violent.
		Crown	9	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	Ditto	Ditto
22nd Sept.	No. 3, upper added	Each haunch	2	$1\frac{2}{10}$	4	0	1	6	Ditto	Ditto	Ditto	Perfect.
		Crown	2	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	Ditto	Ditto
22nd Sept.	No. 3, lower added	Each haunch	2	$1\frac{2}{10}$	4	0	1	6	Ditto	Ditto	Ditto	Ditto
		Crown	2	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	Ditto	Ditto
"	No. 3, main	Haunch, Strood side	9	$1\frac{2}{10}$	4	0	1	6	Ditto	Ditto	Ditto	Ditto
		Crown	9	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	Ditto	Ditto
"	No. 4, lower added	Each haunch	1	$1\frac{2}{10}$	4	0	1	6	Ditto	Ditto	Ditto	Ditto
		Crown	4	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	Ditto	Ditto
"	No. 4, upper added	Each haunch	1	$1\frac{2}{10}$	4	0	1	6	Ditto	Ditto	Ditto	Ditto
		Crown	4	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	Ditto	Ditto
"	No. 4, main	Crown	11	$2\frac{1}{6}$	1	0		9	Ditto	Ditto	1 charge failed	Failure.
21st Aug.	Abutment	Along the front	3	$\frac{1}{10}$	42	0	7	6	Ditto	Clay and rubbish	Ditto	Complete, gentle.
22nd Aug.	No. 1, Pier	Each end	2	$\frac{1}{10}$	133	0	11	0	Ditto	Do. do.	All exploded	Ditto
"	No. 2, Pier	Ditto	2	$\frac{3}{20}$	200	0	11	0	Ditto	Do. and sandbags	Ditto	Ditto
"	No. 3, Pier	Ditto	2	$\frac{3}{20}$	200	0	11	0	Ditto	Do. and rubbish	Ditto	Very complete.



VIEW OF THE EAST END OF THE OLD BRIDGE AT ROCHESTER, AFTER THE DEMOLITIONS IN 18



REFERENCES.

The Crossed Hatching (▩) *shows the parts of the Bridge that were removed by Manual Labour.*
The Hatching to the right (▨) *shows the portion demolished by Mining, by the R.l & E. India Engineers in the Winter of 1856_7, as described in the 7th Vol. of the Professional Papers.*
The Shafts are shewn thus ⊠

PLAN OF THE OLD BRIDGE
AT
ROCHESTER,
shewing the positions of the Charges employed
in its Demolition.

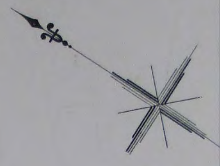


Fig. 1.

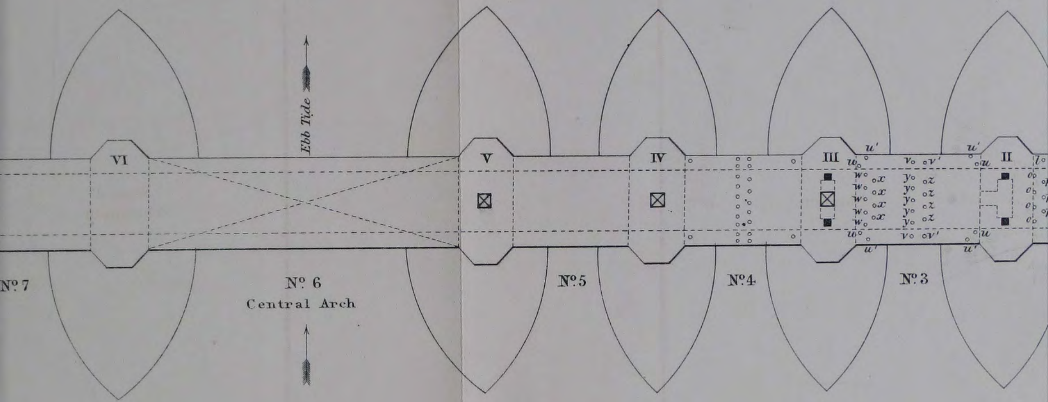


Fig. 2.

ELEVATION OF BRIDGE.

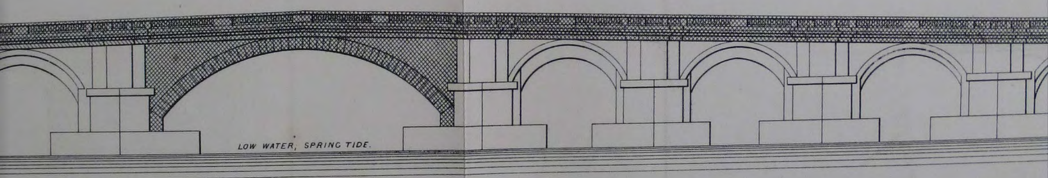
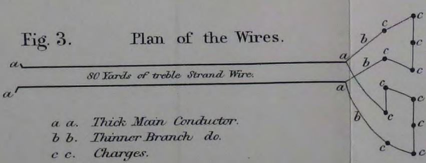


Fig. 3. Plan of the Wires.



Scale, 4

PAPER VIII.

Reports on the Operations of the Royal Engineers at the Taking of Canton, in December, 1857.

By MAJOR G. MANN, R.E., and CAPT. STUART, R.E.

Letter from the Commanding Royal Engineer in China, to the Inspector General of Fortifications, forwarding the Copy of a Letter to the Major General Commanding the Forces, relative to the Proceedings of The Royal Engineer Department at the Capture of Canton, together with Two Sketches of the Ground on which the Operations were conducted.

No. 7. *Royal Engineer Office, Canton, 13th January,* 1858.

Sir,—I have the honour to forward the copy of a letter, which, as head of a department, I was called upon to furnish, stating the services performed by the Royal Engineer Department towards the capture of Canton; it is accompanied by one from Lieutenant Stuart, R.E., who, being the first to escalade the walls as guide to the French attack, is recommended by His Excellency the French Admiral for the Legion of Honour. I also send two sketches descriptive of the field of operation.

The weather from the landing to the escalade was very favourable, being dry and temperate; and the ground was comparatively hard. The 9-pdr. guns, however, could not be brought up in time, notwithstanding every exertion on the part of the Artillery. The only guns brought into position against the walls were 12-pdr. howitzers and 3-pdrs., and these were employed in keeping down the enemy's fire, and, in the left attack, in knocking down the parapet.

The propriety of attacking the town on the eastern side was clearly established, not only as the walls were weaker in trace, in section, and in approach, but because the enemy's attention seemed drawn to the north-west, where their principal force appeared to be stationed, and away from our advance.

It has been generally reported that the Chinese fight well at long ranges, but cannot stand at close quarters, and this was borne out on the present occasion; their firing was pretty good and well sustained for a time, particularly from Fort Lin upon our Troops to the right of the Temple, from Fort Gough and the city upon Fort Lin and its neighbourhood, and from the walls upon our right advance. Otherwise than by distant fire they made only one attempt to repel our force, viz., after the capture of Fort Lin, by the advance of some thousand braves from the neighbourhood of Fort Gough to the shelter of a hill within 500 or 600 yards of our right advance; here they suffered much from the musketry fire of the Marines, and soon retired.

After the escalade, some small detached parties fought much better along the walls, delivering their fire within 20 or 30 yards, and advancing as though for an attack.

From the time of our landing at Honan, since when great exertions have been required from officers and men, I have reason to be entirely satisfied with the conduct of all under my orders: I beg particularly to mention Lieutenant Stuart, who, both during this period, and in the preparations made at Hong Kong for the attack, has been especially zealous and efficient.

I have the honour to be, Sir,

Your most obedient and humble servant,

G. F. MANN, Captain, Com. Royal Eng.

The Inspector General of Fortifications.

Royal Engineer Office, Canton, 4th January, 1858.

SIR,—I have the honour to report on the operations which took place before Canton from the 27th to the 29th ultimo, so far as the department under my charge was concerned.

On the afternoon of the 27th ultimo I landed with the officers, most of the men (ten men being left at Honan to bring up the pontoon bridge) and a portion of the stores, at a spot on the main land opposite to the end of Kupar Island, having been conveyed to this spot from Honan in two gunboats; the Tent-Lascars landed at the same time as a working party, and we were, soon after, joined by a covering party of the 59th Regiment.

I immediately selected three sites, and commenced the construction of three jetties on which the Troops and guns might be landed early on the following day, one of timber, collected from the adjacent village, of strength sufficient to land siege guns, should they be requisite; one of lighter poles and bamboos, for infantry; and the third of earth and stone, to serve as an abutment for the pontoon bridge, when it should arrive; meanwhile a party of Sappers, and the greater portion of the Tent-Lascars, were led beyond the village, and employed under Lieutenant Stuart, R.E., in improving the road towards Canton. The men worked very steadily that evening and the greater portion of the night, the first part of which was bright and moonlit: by 8 o'clock the following morning, 40 feet of the pontoon bridge (all that had arrived) was in use as a jetty; the jetty of light timber was soon after completed to a length of about 40 feet, and by 10 o'clock that for guns was completed, being 10 feet wide and about 60 feet long. The road was rendered practicable for field artillery by widening the causeways between the enclosures which were wet or soft, and cutting through them into the small fields on the higher and harder ground.

These works being completed, a small guard only was left in charge of the stores which had been landed, and the rest were marched to the front; they halted, with the advance of the 59th Regiment, behind the building nearest to Fort Lin, where Lieut. Longley, R.E., with a party of Sappers, had a powder-bag in readiness to advance with the storming party and blow open the gate. This attack however was not made, the fort being taken by entering it through the embrasures.

On the following morning before daybreak, ten Sappers were detailed to accompany Lieutenant Stuart, R.E., and join the French brigade; ten under Lieutenant Longley, R.E., to join the brigade of seamen; and six under Lieutenant Trench, R.E., to accompany me to the Marine battalion attached to them, advance with them and reconnoitre in their front; the remainder of the Sappers, under Lieutenant Ffinney, were left as a reserve with Colonel Graham's brigade. Colonel Lemon's battalion of Royal Marines was found within a few hundred yards of the north-east angle of the city, being in advance of the seamen's brigade. After a little skirmishing with some Chinese, who soon retired towards Fort Gough, a position was attained in the village, and held unopposed, except from the city walls

The Major General Commanding had now arrived, and ordered out a covering party, with which he advanced to the extreme end of the village. By proceeding to the edge of the ravine, a little in front of it, which borders the city walls at this part, I was enabled to report to him as to their height, and the nature of the intervening obstacles. It was now half-past 7 o'clock, when the Naval brigade advanced to the front with their scaling ladders, which were placed, part in a square near the front of the village, part on the edge of the pond adjacent, in readiness for the assault that was ordered for nine o'clock. The enemy's fire from the city walls and from Fort Gough continued to be well sustained from gingalls, cannon, and rockets, until about 20 minutes before 9 o'clock, when it suddenly ceased, and a distant shout announced that the walls were already scaled; the seamen immediately rushed forward with their scaling ladders and were soon on the wall.

Meanwhile the French, supported by Colonel Graham's brigade, were advancing on the left, and had taken up a position 300 yards from the right attack, but hidden from it by the contour of the ground. The operations in this quarter are very clearly stated in a Report from Lieutenant Stuart, R.E., a copy of which I beg leave to enclose. The troops in this quarter mounted the city walls at 20 minutes before 9 o'clock, the Right Division immediately following; they, together, drove the enemy along the line wall to the north, and successively from the North-East gate, 5-storied pagoda, Magazine Hill, and Great North Gate. The 59th Regiment, turning to the south, took and occupied the east and south-east gates.

I have every reason to be satisfied with the conduct of the officers and men under my orders. On the night of the 27th, in particular, when so much depended on their exertions, they worked with the zeal and energy expected from them. Corporal Way and Sapper Monds, of the 10th Company, I may mention as deserving the highest praise.

I have, &c.,

(Signed) G. F. MANN, Capt. Com. Royal Eng.

The Assistant Adjutant General,
&c., &c., &c.,
Canton.

Head-quarters, Canton, January 3rd, 1858.

SIR,—I have the honour to report that in obedience to your orders, on the morning of the 29th ultimo I proceeded with a detachment of 2 non-commissioned officers and 7 privates of my Company of Volunteer Sappers, and placed myself under the orders of the French Commander-in-Chief, with whom I proceeded to make a reconnaissance of the proposed point of attack, from the most advanced French post, viz., the village or suburb to the north-west of the east parade ground. After this, and up to about twenty-five minutes before the assault, I remained with the French admiral as an extra aide-de-camp.

About 7 A.M., and after the 59th Regiment had occupied the line of houses running parallel to the creek or ditch, on its east side, the French Commander-in-chief moved his field-guns to the rear of the village before-mentioned, to cover the advance of his storming columns, which were soon after halted behind some rising ground to the north-east of the village, which afforded some protection from the enemy's fire from the walls, which was tolerably heavy and well directed.

During the time when the columns were thus halted, the bamboo scaling ladders were lengthened, as far as time and means permitted; for the original length of 30 feet was deemed barely sufficient to reach the bottoms of the embrasures, which we calculated to be close to that height.

After about half-an-hour's well directed fire, the 59th Regiment had very nearly silenced that of the enemy from the walls in front of them, leaving however a sharp fire not overcome on each flank.

The French Commander-in-Chief seized this opportunity of throwing his stormers into the houses and shelter occupied by the 59th Regiment: this was about 20 minutes past 8 o'clock. At this time I quitted the Admiral, and proceeded with my sappers to the "house of aged females," held by the right wing of the 59th Regiment, part of which lined the west bank of the ditch.

As the sappers carried their tools with them, I at once set them to work to clear a passage for the ladders, and to pitch the debris into the ditch, the water in which was however only knee-deep.

Leaving the men thus employed, I advanced up the muddy creek or rivulet, which debouches from the city walls and joins the ditch at this point. I advanced up to the wall, and found it to be faced with stone, having a slope or batter of about one-fourth, and apparently about 27 ft. high. About 20 yards to the south of the stream coming from the city wall, a flank, of about 15 feet projection from the face of the wall, was situated: to the left, or south, of this flank, Captain Rotton's battery, with four French field-pieces under Lieutenant-de-vaisseau Veriot, had knocked over the parapet wall for a distance of about 35 feet, but had reduced the actual height of wall, for escalade, by only a few inches. Lastly I found that the stream from the city wall, by being arched over, offered a height of enceinte less by 3 or 4 feet than that of the adjoining portions. I deemed this such a suitable point for escalade that I reported its nature, at once, to the French officers, and to Brigade Major Luard of Colonel Graham's brigade.

About 10 minutes before 9 o'clock, 2 ladders were planted on the top of the arch, on the *right* of the flank, some others being at the same time raised at the breach on the *left*; the two parties assaulted about the same time, but which reached the top first is a point that cannot be solved. The party which entered by the left proceeded to take and hold the "East Gate."

The party on the right, with which I entered, pursued the flying Chinese, who however fired every piece of cover they came to; only once, seeing our small numbers, did they make a stand, till we came to within 30 yards of them. We were soon joined by the British Naval Brigade, and we advanced together to "Great North Gate," taking possession on our way of "Little North Gate," "5-storied Pagoda," and "Magazine Hill."

I have great pleasure in bringing to your notice the steady, soldierlike conduct of the detachment of Volunteer Sappers who accompanied me, particularly of Corporal Perkins, who never quitted me, and was amongst the first on the wall, also of Private Daniel Donovan. These two men were employed at "Great North Gate" in rendering it more defensible.

Having seen "Great North Gate" well occupied by the Naval brigade, I returned along the wall, and having collected my men and materials, proceeded to the small south gate, which you are aware was that night rendered capable of a stout defence.

I have the honour to be, Sir,

Your most obedient servant,

W. J. STUART, Lieut. Royal Eng.

PAPER IX.

Reports on the Demolition of the Forts at Canton, in January, 1858, by Major Mann, Major Fisher, Capt. Stuart, and Lieut. Longley, Royal Engineers.

Letter from the Commanding Royal Engineer in China to the Inspector General of Fortifications, forwarding Reports on the Demolition of the Five Forts to the North and East of Canton.

Royal Engineer's Office, Canton, 20th February, 1858.

Sir,—I have the honour to enclose Reports by Captain Fisher and Lieutenants Stuart and Longley on the demolition of the five forts outside the North and East walls of Canton.

It was deemed advisable to destroy these forts, to prevent a hostile force taking possession of them and using them against us; to weaken in some measure, without destroying, the defences of the city; but, above all, to give proof to the inhabitants that we are entirely masters of the place, and likely to remain so.

The Major General Commanding in the first instance ordered, on the 30th December, that Fort Gough should be made untenable by an explosion, to take place one hour afterwards, viz., at $1\frac{1}{2}$ P.M.; and this was effected by sinking a shaft in the south-east corner about 3 feet deep, loading it with about 30 lbs. of Chinese powder, found within the fort, and tamping with a mound of earth and paving stones; this effected a practicable breach. The working party consisted of 10 sappers, and the covering party of about 120 seamen.

The Major General Commanding, in concert with the French Admiral, next ordered a hasty demolition of the walls generally of Fort Gough and of Fort Kung-kik, opposite the north gate, and that both should be destroyed on the 1st January. As no guard had been left at either fort the small quantity of powder which each contained was removed by Chinese during the night; an ample store, however, had been found in the powder factories within the city, close to our position, and was then being removed by the Major General's order, to be destroyed, some attempts having been made by the Chinese to fire it. Ample working parties were allowed, of the British Navy for Fort Gough, and of the French for Kung-kik, but there were no means of obtaining a sufficiency of working tools, nor of fuze or powder hose. The aggregate number of day's work of a labourer employed at the two forts amounted therefore to no more than 120; and the quantity of powder used, and which exploded (2,174 lbs.), was in excess of that due to the thickness of the walls, but it did not in every case effect demolition, from the want of sufficient tamping and depth of shaft. The walls of Kung-kik were however rased to below the level of the terreplein, and those of Fort Gough were so shattered to the foundation as to be useless and irreparable.

The demolitions of Marine Fort, and of Pak-kik Fort, were ordered on the 20th January, and that of Fort Lin, with the ruins of Forts Gough and Kung-kik, on the 25th January. All were entirely demolished, so that no stone is to be seen standing except one or two fragments of Fort Gough and the inner retaining wall of Kung-kik, which the charges, necessarily placed outside, did not generally throw down, though they shattered every part of it.

The powder exploded in the five demolitions on these two days was 9,199 lbs., and the labour in preparing for them was 794 day's work. The powder appeared good for mining purposes, a slight addition only to Sir Charles Pasley's rule ($\frac{3}{20}$ l.l.r.^{3} for charges behind masonry), being generally quite effective.

I have the honour to be, Sir,

Your obedient humble servant,

G. F. MANN, Capt. Com. Royal Eng.

The Inspector General of Fortifications.

Report on the Demolition of Fort Gough, near Canton, on the 1st January, 1858, by Lieut. Longley, R.E.

Fort Gough is 143 feet square, and is situated on a hill about 600 yards east of the 5-storied Pagoda, outside the walls of Canton, the whole of which it commands, with the exception of Magazine Hill Fort, which is at the same height above the sea. Its foundations are of granite, resting on a sand-stone rock, and vary from 3 to 7 feet in height, following the irregularities of the rock: above this is a brick wall, 3 feet thick and 13 feet high, loop-holed and embrasured, as shown in elevation.

In the interior is a tower or keep, 50 feet square, and 26 feet in height, with granite foundations 3 feet high, the remainder being brick-work, 8 feet thick, with earth in the centre. On the top of the keep is a rectangular building made use of as a powder magazine, surrounded by a loop-holed and embrasured wall, 7 feet in height, as seen in section. Round the foot of the keep is a ledge 10 feet wide and 9 feet high, faced with masonry. On three sides of this are sheds used for barracks, and for a powder-magazine and rocket shed.

The entrance to the fort is on the side next the city, by a flight of steps leading through an archway into the lower story, and through another arch and gateway into the keep. There was a gate under each arch, made of 3-inch wood, faced with sheet iron.

On the 30th December, 1857, orders were received for a hasty demolition of this fort in the best manner the means at hand would permit; and the explosion was to take place at 4·30 P.M., on the 1st January, 1858. The time for the execution of this being so limited, and the only tools available being a few picks and shovels (the remainder of the Engineer stores being still on board ship), it was necessary to use large charges, and expedients for tamping, priming, and firing, not ordinarily employed when the usual materials can be obtained. All the powder used was Chinese, found in the magazines inside of the city walls, whence any amount could be obtained. This powder* was a mixture of coarse and mealed powder, evidently inferior to that of English manufacture, which induced me to increase the charges of the mines considerably beyond those laid down in the Chatham Instructions for military mining.

* It was probably better for mining than for Artillery, or where instantaneous ignition is necessary.—G. F. MANN, Capt. Com. R.E.

Most of the mines were fired by means of a portfire stuck into a split bamboo, filled with powder, leading to the charge ; and the remainder by Bickford's fuze, collected from Her Majesty's ships in the river.

TABLE OF CHARGES.

Position of Mine.	Charge in lbs.	Effect.
LOWER STORY.		
4 shafts sunk in the angles to a depth of 6 feet	40	Demolition complete.
4 charges placed in horizontal weep-holes, from the exterior, 5 feet deep, on the west side of fort	15	2 of these failed ; 2 effected demolition.
5 charges placed in weep-holes on south side	80	2 succeeded, the remainder failed.
4 charges ditto, ditto, on east side	100	Loosened the masonry round the holes.
6 charges, ditto, ditto, on north side	40	2 succeeded, the remainder failed.
IN THE KEEP.		
4 charges placed in the angles ; shafts being sunk 7 feet deep ..	18	3 of these produced complete demolition. The other bulged the masonry about 8 inches beyond its original position.
1 gallery driven horizontally above the masonry foundation ; charge placed near the centre of the keep	800	Did not explode.

LIST OF WORKING PARTIES, &c.

	Dec. 31st.		Jan. 1st.
Sappers	12	......	25
Pioneer Sailors (working party)	3	......	1
Sailors (covering party)	75	......	60

By the explosion of these mines the walls were thrown down, as shewn in sketch, the remainder of the walls, although left standing, were much shaken, and in some instances displaced a few inches.

On the 20th January, ample stores having arrived, orders were given for the demolition of the ruins and foundations of Fort Gough and Blue Jacket Fort, and also for that of Fort Lin.

DEMOLITION OF THE REMAINING PART OF FORT GOUGH.

In the lower story 26 shafts were sunk behind the revetment, to a depth varying from 5 feet to 8 feet, according to the height of the masonry, taking care to sink to within a foot of the bottom of the foundation, with returns 3 feet in length, in which charges were placed. These charges were 15 feet apart, and at 2 lined intervals, and consisted of 76 lbs. of Chinese powder each, placed in two sand-bags, cut open at the place of contact. Behind each pier of the entrance gateway shafts were sunk 7 feet deep, with returns 4 feet long, under the foundation, in each of which a charge of 138 lbs. of Chinese powder, in 3 sand-bags, was placed.

In the keep 3 horizontal galleries, 8 feet in length, were excavated through the brick-work, above the masonry foundation, in the centres of the north, south, and east sides. At the end of each of these galleries two returns were driven, right and left, through the earth at the back of the masonry, inclining downwards.

The returns on the east side were 8 ft. 0 in. long and 5 feet below top of masonry.

—	south	6 ft. 0 in.	—	5 feet	—	—
—	north	6 ft. 9 in.	—	5 feet	—	—

In each of these mines charges of 138 lbs. were placed.

On the right and left of the archway horizontal galleries were driven, 12 feet long, and 3 feet 2 inches below the masonry foundation of the keep, in which charges of 92 lbs. were placed.

In the steps leading to the door of the keep, a shaft 10 feet deep was sunk, and a return driven, 4 feet long, at the end of which a charge of 92 lbs. was placed.

In the landing place, at the bottom of the steps leading to the exterior gate of the fort, a charge of 30 lbs. was placed at a depth of 5 feet, in a return 3 ft. 6 in. long.

Table of Working Parties.

	January				
	21st,	22nd,	23rd,	25th.	Total.
Sappers	25	31	25	30	111
Royal Artillery.	24	—	—	—	24
Royal Marines.	25	44	—	75	144

Powder hose was used to connect each charge with a split bamboo filled with powder: at the top of the bamboo half a portfire was placed, well kneaded round the junction with clay, allowing 7 minutes to elapse between the ignition of the portfire and the explosion of the mine.

The mines were fired at 3 P.M. on the 25th January. Notwithstanding the above precautions, two mines in the western side of the fort went off about half a minute after the portfire was lighted, but fortunately did no injury to any of the sappers employed in lighting the portfires, beyond a slight bruise on the back of Sapper Graham from a stone.

The remainder of the mines, with the exception of three, exploded, and produced complete demolition.

G. LONGLEY, Lieutenant R.E.

Report on the Demolition of Kung-kik Fort.

By CAPTAIN STUART, R.E.

Head-quarters, French Force, Canton, 5th February, 1858.

Sir,—I have the honour to enclose a plan* of "Kung-kik Fort," Canton, showing details of the two demolitions of the 1st and 25th January, which I was ordered by the French Commander-in-Chief to superintend.

* This is omitted here, as it does not show the mines distinctly. In the 1st demolition they appear to have been about 11 ft. apart, and 18 charges were used, containing 908 lbs. of Chinese powder.—Ed.

1st Demolition.

On the 31st December, 1857, I started in the morning, with a French working party of sailors and two sappers of the Royal Engineers, to effect a hasty demolition of Kung-kik Fort; and having made a hasty plan of the fort, I found that I had only sufficient men and tools to form the mines for the main wall leaving untouched the outer terrace or foundation platform.

On examination, the walls appeared to be $5\frac{1}{2}$ feet thick, which thickness was therefore assumed as the length of the line of least resistance. On one side of the fort the wall proved to be of this thickness, but on the other sides it increased to 8 feet, at 5 feet below the surface; and the large blocks of granite of which it was composed prevented the shafts being sunk to the required depth, so that the charges had to be placed in the best positions that circumstances and time admitted of, some of them being increased in strength as far as the stock of powder permitted. The lines of least resistance on these sides varied between 6 and 8 feet, as shewn in section.

At half-past 4 on the afternoon of the 1st January, the 18 mines were fired; they all appeared to have exploded, except one, and this charge was afterwards uncovered in the 2nd Demolition. The fort was rendered completely useless, but in consequence of the charges not being placed as low down as desirable, the foundations were not destroyed. The gateway and steps were left standing by desire of the French admiral.

The fort mounted 14 guns, several of which, pointing north, were of large calibre. The plan will show the amount of powder used, and other details.

2nd Demolition.

On the 25th January the outer terrace was destroyed, the working party consisting of French sailors and 6 sappers. The work was commenced on the 22nd; but on the 23rd, the day named for the explosion, it was postponed until the 25th.

Presuming that the walls would prove to be between 7 and 8 feet thick, I assumed 8 feet as the length of the line of least resistance, and, calculating for 2-lined craters, I placed the shafts 16 feet apart; but subsequently I changed the length of the line of least resistance to $9\frac{1}{2}$ feet, with the view of more effectually damaging the foundations of the fort, left standing after the first demolition. For five of the mines, the irregular nature of the wall rendered a further extension of the line of least resistance to $10\frac{1}{2}$ ft. necessary.

The charges* were calculated at $\frac{3}{10}$ l.l.r ^{3} (in pounds, not in catties as shown on the plan for the 1st Demolition), and the complete, and rather violent, 2nd Demolition, would seem to show that Chinese powder is little inferior, for *mining* purposes, to that of European manufacture; although, from its slower ignition, it is not so strong by a good deal for artillery purposes.

The train was formed of hollow bamboos filled with common powder, and fitted with portfires in wet clay; and, of the mines prepared in this way, in this fort and at "Pak-kik," not one missed. As the somewhat rough arrangements could not be carried out to such a nicety as to ensure the several mines exploding at the same moment, it might be supposed that the falling debris of one mine would be very likely to derange the fuze

* In the 2nd Demolition 17 charges were used, containing 2,175 lbs. of Chinese powder.—Ed.

of another, but the precaution of heaping the earth round the bamboo and portfire, and letting the latter run about two inches into the bamboo, seemed to be perfectly sufficient to guard against this danger.

The demolition of the terrace was most complete, and although the explosion failed to bring down most of the foundations of the fort above mentioned, still, in all cases, from the craters extending quite to the foundations, and even underneath them, they were left in such a position that in all probability the next heavy rains will cause them to fall. In parts where some of the larger charges were placed these foundations were quite shattered.

I have the honour to be, Sir,
Your obedient servant,

W. J. STUART, Lieut. R.E.

The Commanding Royal Engineer in China.

Report on the Demolition of Pak-kik Fort.

By CAPT. STUART, R.E.

Head-quarters, French Force, Canton, 5th February, 1858.

Sir,—I have the honour to enclose a plan* showing details of the demolition of "Pak-kik" Fort, on Blue Jacket Hill, north of Canton, which took place on the 20th ultimo, under my direction, the working party being composed of French sailors, assisted by six sappers of the Royal Engineers.

The demolition was most complete. The Chinese powder appears to be as strong for blasting purposes as that of European manufacture.†

The shafts were commenced at distances from each other of 14 feet, the thickness of the wall being supposed to be about 7 feet; but, on examination, the wall proved to be from 8 to $8\frac{1}{2}$ feet thick; the charges were therefore placed at less than two lined intervals.

I have the honour to be, Sir,
Your obedient servant,

W. J. STUART, Lieut. R.E.

The Commanding Royal Engineer in China.

Report on the Demolition of "Marine Fort," Canton, Blown up 20th January, 1858.

By MAJOR FISHER, R.E.

This fort was situated on the extremity of the spur of the hill on which Fort Gough stood, and was distant about 800 yards from the city walls. It was of an elliptical form, the axes being 75 and 67 feet long respectively: it was paved with granite, and mounted 10 guns, which fired through covered embrasures. (See Plan and Section).

The ground within the fort was, on an average, 9 feet above that outside, and the interior was gained by means of granite steps, passing under an arched doorway.

* This plan is only a slight one, and is omitted here, but it shows the charges of about $\frac{1}{5}$ l.l.r.^{3}, placed at the level of the ground outside, with l.l.r. 7″ 9′.—Ed.

† Shown to be nearly so, particularly in the demolition of Fort Lin; but at all the forts demolished the charges were slightly in excess of Sir Charles Pasley's rule, except when the walls were previously shattered.—G. F. Mann, Capt. Com. Royal Eng.

The walls, from the foundation up to a level of about 3 feet above the inner ground line, were built of granite, and were about 4 feet thick from top to bottom, and without counterforts. They were surmounted by a battlemented brick wall, and at a height of 5 feet above the inner ground line, a banquette, or step, encircled the fort, above which the thickness of the wall was reduced to 1 foot 6 inches; the banquette was mounted by means of a flight of brick steps on each side of the entrance, and the spaces between the battlemented portions of the parapet wall were loop-holed.

The clear width of the entrance was 9 feet, and the height from the ground line to the crown of the arch was 15 feet.

The piers were 8 feet 6 inches by 6 feet, and were built of solid granite to a height of 3 feet above the inner ground line; and all above that level was built of brick. The gateway was surmounted by a parapet wall.

The conditions of the demolition were, that the fort was to be most completely destroyed, and within a limited time, but that sufficient working parties would be allowed for the work. Chinese powder was also to be used.

Shafts were sunk, 22 in number, at a distance of 8 feet from the face of the wall, and at central intervals of 7 feet 6 inches, to a depth of from 5 feet 6 inches to 6 feet 6 inches, according to the level of the ground outside. From the bottoms of the shafts, galleries were driven, 2 feet long, towards the back of the wall; at the extremities of these the charges were lodged, thus making the l.l.r. 6 feet, and the intervals between the charges was 9 feet throughout.

The charge for each mine was calculated at $\frac{3}{20}$ l.l.r.^{3} $= 32\frac{1}{2}$ lbs., but, allowing for the Chinese powder being less strong than English, they were fixed at 40 lbs., and made up in sand-bags.

Chambers were made in the centres of the piers, on a level with the top of the granite work, to bring down the arch, and assist the charges placed underneath; on which account the charges were heavy (40 lbs. each).

Sufficient time was not allowed to sink the shafts deep enough to get under the piers from the interior, nor could they be sunk on the outside of the fort, as the ground was a hard granite rock at a little depth below the surface. Accordingly, from the bottoms of the shafts nearest the piers on each side, the galleries were driven towards the angles of the piers, instead of directly towards the walls, and a charge of 80 lbs. was lodged at the extremity of each.

The tamping was of clay and brick, and in no case was it blown out.

Only a small quantity of powder hose could be procured for the firing, and no Bickford's fuze, therefore bamboos were made use of; they were split, and the joints removed, after which they were tied up again, and filled with powder, the junction between the end of the bamboo at the bottom of the shaft, and the charge, being made by powder hose. The bamboo held about 6 lbs. of powder in a length of 10 ft. A piece of portfire was fixed in the top of each bamboo, and each mine was fired separately, but simultaneously, a man being charged with the lighting of each.

The effect was very good, and the demolition was complete, but not violent; no stones were projected beyond 60 yards.

Abstract of Powder used.

22 charges of 40 lbs	880 lbs.
2 — 80 lbs	160 -
Total powder used	1,040 -

Strength of Working Party.

Royal Engineers	1 serjeant and 25 rank and file.
Infantry	50 —
Actual time of working	$16\frac{1}{2}$ hours.

(Signed) ARTHUR C. FISHER, Capt. Royal Eng.

Report on the Demolition of Fort Lin, Canton, Blown up 25th January, 1858.

By MAJOR A. FISHER, R.E.

This fort* was of an elliptical form; the interior axes were 65 and 55 feet long respectively; the ground line of the interior averaged 11 feet above the ground outside; the fort was entered by means of a flight of granite steps, at the head of which was an archway closed by a strong door, 3 inches thick and sheeted with iron.

The fort contained a series of slightly built brick buildings, which had been partially destroyed by an explosion on the day of the taking of the fort; these buildings occupied the whole of the interior of the fort, with the exception of the space actually required for working the guns, which were 11 in number.

The parapet wall was battlemented, and had loop-holes pierced for musketry and arrows. A banquette ran all round the fort, the guns firing through covered embrasures underneath it. It was mounted by means of a flight of steps on each side of the entrance.

The walls, from the foundation up to the ground line, were built of granite; the thickness at the foundation was 7 feet 6 inches, and at the ground line 4 feet; the portion above the ground line was built of brick, and there were no counterforts.

The piers of the gateway were 10 feet 6 inches by 7 feet 6 inches, and of solid granite up to a height of 3 feet above the ground line; the remainder of the gateway was built of brick. There was an open shed covered with tiles, on the top. The clear width of the entrance was 10 feet, and the height to the crown of the arch was 15 feet.

The conditions for the demolition were as follows:—1st. That the fort was to be most completely destroyed, but in a limited time; 2nd. Sufficient working parties of the Line could be given, but the Royal Engineer parties were to be small, on account of other works being carried on at the same time; 3rd. Chinese powder was to be used.

Shafts, 13 in number, were sunk 11 feet apart, and at a distance of 10 feet from the foot of the wall, to a depth, varying according to the level of the ground outside, from 8 feet 6 inches to 10 feet; from the bottoms of these shafts, galleries, 2 feet in length, were driven towards the walls, except in the case of the mines nearest to the entrance, which were driven towards the angles of the piers. The charges were about 12 feet apart, and the lines of least resistance 8 feet long.

Chambers were made in the centres of the piers, at the level of the top of the granite (or 3 feet above the ground).

The charges along the walls were calculated at $\frac{3}{20}$ l.l.r.^{3} = 77 lbs., but, allowing for the inferior quality of Chinese powder, they were fixed at 85 lbs. each.

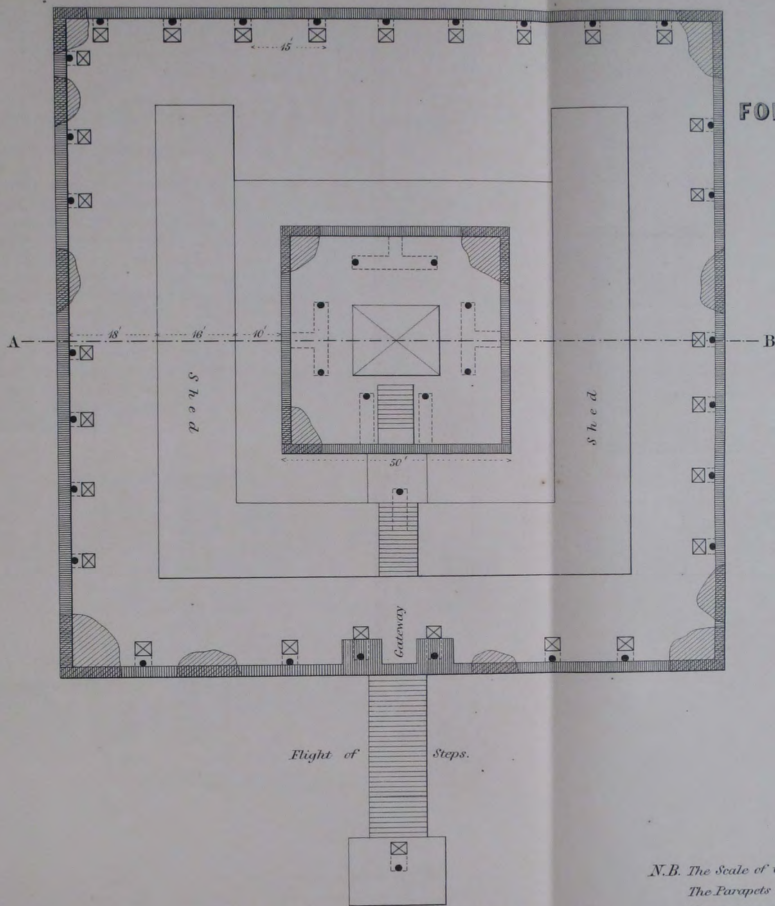
In the case of the 2 mines at the back of the piers, the line of least resistance being 9 feet, and not in the direction of the piers, a double charge was used.

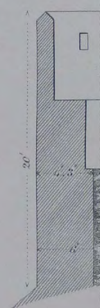
A charge of 40 lbs. was put in the centre of each pier, and 18 lbs. in the centre of the steps.

* The Plan of this fort is omitted here, as it closely resembles the Marine Fort.—Ed.

PLAN OF

FORT GOU





N.B. The Scale of the Plans is 3(
The Parapets are shewn thu
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The Shafts are shewn thus
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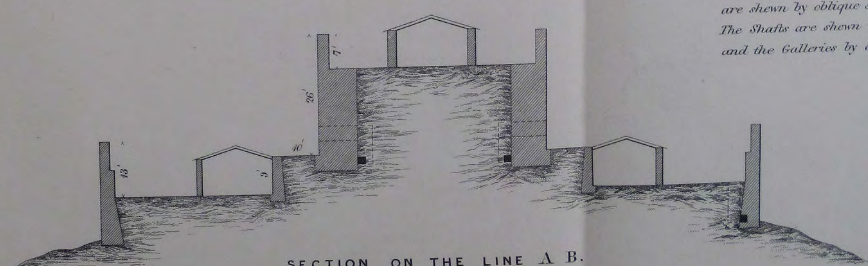


SECTION ON THE LINE A B.

Scale $\frac{1}{360}$

The brick buildings in the centre of the fort were pulled down by hand before commencing the mines.

The nature of the soil was clay, and at the bottoms of some shafts rock was met with.

The tamping was of brick and clay, and in no case blew out, bricks were piled over the tops of the shafts to a height of 2 feet to give additional weight to the tamping.

The mines were fired by means of bamboos, split, cleared of the joints, and tied up; these were filled with powder, and connected, at the bottom of the shaft, with the charge, by means of a short length of powder hose. A piece of portfire was fixed on the top of each bamboo, and the charges were fired separately, but simultaneously.

The effect was very complete, but rather violent; three of the charges did not explode, the cause being, in two instances, that, in tamping, some clay had entered the bamboo, through the joints; and in the other, that the portfire had been knocked out of the bamboo, by the explosion of an adjacent mine, before it had ignited the powder, neither of which failures would have occurred with proper materials.

However, the charges having been placed at $1\frac{1}{2}$ lined intervals, the explosion was sufficient to bring down the whole fort.

Abstract of Powder used.

11	charges of	85 lbs.	=	935 lbs.
2	—	170 lbs.	=	340 lbs.
12	—	40 lbs.	=	80 lbs.
1	—	18 lbs.	=	18 lbs.
		Total........		1,373

Working Party.

Royal Engineers	1 serjeant and 15 rank and file.
Infantry	30 —
Actual time of working..	17 hours.

ARTHUR C. FISHER, Captain, R.E.

PAPER X.

Account of the Bridge of Rafts Constructed across the Harbour of Sebastopol, by the Russians, under the Directions of Lieut. General Buckmeyer.

The accompanying Plate represents a portion of the bridge constructed across the harbour of Sebastopol. It stood well against the action of winds and waves, and 12 or 13 projectiles struck it without doing it any material injury.

The following short account of it has been translated from the Journal of the Siege, written by General Niel, of the French Corps du Génie :—

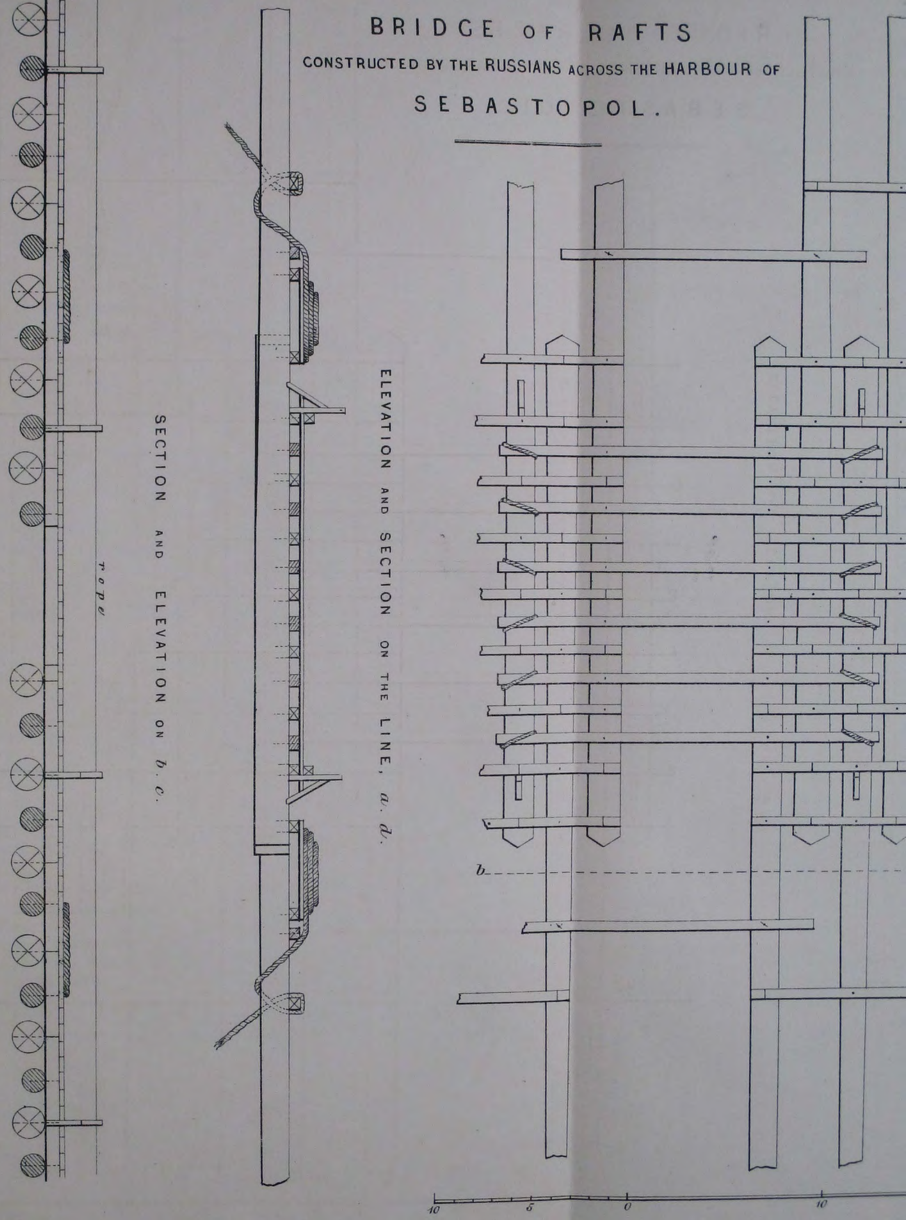
" It was in the month of August, 1855, that the Russians constructed the great bridge of rafts across the harbour of Sebastopol, so as to unite Forts Nicholas and Michael; it was undertaken at the suggestion of Lieutenant General Buckmeyer, who constructed it with remarkable rapidity, commencing at both ends simultaneously.

" The construction of this bridge, which was more than 1,000 yards long, and the roadway of which was 17½ feet wide, afforded the Russians a communication more certain, easy, and rapid than that which could be effected by means of steamers, and it rendered Sebastopol a real bridge-head. The garrison could keep their reserves secure from the effects of our fire, on the north side, and yet the whole Russian army could have united with the garrison during the night, and have attacked our siege works unexpectedly. If we became masters of the place the garrison ran no risk of being taken prisoners, for they could at any time retire to the camps on the north side, and remove or destroy the bridge."

It was opened for the passage of troops on the 27th August, and was entirely removed by mid-day on the 9th September, or 48 hours after the Malakoff was assaulted.

BRIDGE OF RAFTS

CONSTRUCTED BY THE RUSSIANS ACROSS THE HARBOUR OF SEBASTOPOL.



PAPER XI.

Reports on the various kinds of Iron Gabions which were in use at the Royal Engineer Establishment at Chatham, during the Summer of 1856.

By CAPT G. PHILIPS, Royal Engineers.

Royal Engineer Establishment, Brompton Barracks, Chatham, October 28th, 1856.

Sir,—In obedience to your orders, I beg to lay before you a Report on the various iron gabions that have been in use at this Establishment during the summer.

The accompanying Table shows the dimensions, weight, &c., of each of these kinds of gabions, and also of the common brushwood gabion in ordinary use.

The advantages and disadvantages of each of these kinds of gabions I have endeavoured to show in the remarks that follow this Table.

Nature of Gabion.	Pattern.	Dimensions.	Weight empty.	Weight full.	Time in making	No. of men to make each.	Cost.	Durability.	Remarks.
		′ ″ ′ ″ ′ ″	lbs.	cwts.			s. d.		
Wood	Common round	2 0 × 2 0 × 2 9	60	5½	3 hrs.	3	4 11	1	Green wood.
			40	5¼	3 —	3	6 2	1	Dry wood.
Iron	Capt. Tyler's round	2 0 × 2 0 × 3 0	26	5⅞	10 min.	2	8 11	5	
Do.	Sebastopol round	2 0 × 2 0 × 2 9	53	5½	1½ hrs.	3	9 0	5	
Do.	Square	2 0 × 2 0 × 2 9	59	5⅞	1½ —	3	10 1½	4	
Do.	Serjeant Major Jones's round	2 0 × 2 0 × 2 9	26	6⅛	5 min.	2	3 0	5	20-in. guage.
Do.	Messrs. Cottam & Allan's round		25	5½	*		†	2	* Ready made
Do.	Capt. Morrison's square	1 6 × 1 6 × 2 · 8	21	4⅞	*		†	3	† Expense not known, but it would probably be 10s. or thereabouts.

1. Captain Tyler's Sheet Iron Gabion.—Captain Tyler's gabion is composed of a single sheet of galvanized iron of the length of the circumference of the proposed gabion (6′ 2″) joined at the edges by three pieces of wire; it has the following great advantages over the ordinary brushwood gabions, viz., its small weight, portability, comparative indestructibility when not disturbed, and the short time it requires in putting together.

Its disadvantages are the great noise it makes when carried, which I consider totally unfits it for flying sap or any other secret operation; the difficulty of moving it by means of sap-forks in sapping; its want of stiffness when put together, which prevents it keeping its shape when subjected to a moderate pressure; also its want of hold on the ground when placed for trench work, which makes it require much care in filling it, or it will be overturned.

I consider it well adapted to resist the explosion of heavy guns in embrasures, and also for the revetments of batteries and of field works that are likely to last for a considerable period, but unfit for the revetments of trenches formed by any kind of sap.

2. SEBASTOPOL GABION.—The Sebastopol gabion is formed of $1\frac{3}{4}$-inch hoop iron, nailed in single pieces on wooden pickets (13 in number to the round gabion, and 12 to the square one). About 200 running feet of hoop iron are used in each gabion.

The advantages of this kind of gabion are that it is very strong; that it is made in a shorter time than the ordinary wooden gabion, and that it can be taken to pieces and packed; also that the materials for making it will always be found with an army in the field.

Its great weight is its only objection, but this is a great one; it is also expensive in England, but that does not apply to its value on service.

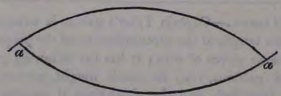
3. SERJEANT MAJOR JONES'S GABION.—Serjeant Major John Jones's Gabion is formed by bands of sheet iron $3\frac{1}{4}$-inch wide, fixed on wooden pickets $1\frac{1}{2}$-inch by $\frac{1}{2}$ an inch. Each band is composed of a single strip of sheet iron, of the length of the circumference of the gabion, the ends being fastened together by two buttons at one end, fitting into two slots at the other; 12 pickets are used. This gabion is made by laying the first band on the ground, driving the pickets round it in their proper places, alternately on the outside and inside of the band, and touching it; the next band is then placed on the top of the pickets (taking care that the pickets that were outside the other band are now inside of it, and *vice versa*) and is pressed down on to the band first placed. Each of the bands is placed in this manner, and the gabion is finished in five minutes by two men. There are a couple of holes in each band for the insertion of pickets for carrying it.

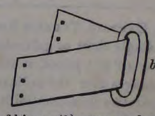
The advantages of this gabion are very great. It is very light and cheap, is easily made, and takes but five minutes to make or unmake; it is very portable, is easily repaired by the substitution of new bands for damaged ones, and it is rigid when made.

I consider that it combines the advantages of all other iron gabions, without their disadvantages, for they do not make a noise in carrying, nor do they alter their shape when being filled, or when filled; and I consider them by far the most serviceable gabions yet used.

I recommend however that they should be made of galvanized iron, and that the pickets should be $\frac{3}{4}$-inch thick, instead of $\frac{1}{2}$ an inch, to increase their rigidity when put together.

4. MESSRS. COTTAM AND ALLAN'S SHEET IRON GABION.—Messrs. Cottam and Allan's gabion is made of a couple of sheets of galvanized iron joined as at *a* in Plan.





The junction of the sheets is effected by means of a sort of hinge, (*b*) composed of an oval ring of wrought iron, to which is attached a piece of sheet iron. The ends of this piece of sheet iron are brought together, passed through a slit in one sheet of the gabion, and riveted to the other. 3 of these hinges are used for each sheet. The thickness of the iron oval ring being greater than the width of the slit prevents its passing through it, and thus makes it act as a hinge, the strength of which evidently depends upon the power of the sheet iron sides to resist the tendency of any pressure to tear the ring through the slit.

This gabion is light and portable: its expense is not known, but probably would be about 10s. I consider it however unfit for use on account of the following great disadvantages:—It makes a noise in carrying, it will not keep its shape when filled, it has no hold of the ground, and the sheets composing it are not sufficiently strong to prevent the destruction of the hinges, by the iron rings being drawn through when the gabion is filled and subjected to an ordinary pressure in a trench, and thereby causing the destruction of the gabion.

5. Sheet Iron Gabion Proposed by Capt. Morrison, R.E.—Capt. Morrison's gabion is a square one, composed of four separate sides of galvanised iron, fastened together by 4 iron pins running through hinges on the edges of the iron sheets. It is only 1 foot 6 inches square. It is proposed by Captain Morrison to be carried in pieces, and put together by a working party at night on the spot where it is to be used.

Only one of this kind of gabion has been sent to the Establishment, and consequently it has not had a fair trial, but it appears to me that it is decidedly not a good gabion, for it is free to move at the angles, and consequently would shut up with a very slight pressure from without, which must occur when a row of them are being filled, and any of them fall to one side; and this is unavoidable in trench work at night.

One man is supposed to carry three of them (in pieces) and put them together on the spot he works on; I consider that this, on service, with an ordinary working party, is impossible, for if either of the sides, hinges, or hinge pins get bent (and I cannot see how this is to be avoided), they cannot be put together, and, consequently, are useless. Or most likely some of the pins would be lost, and the gabion would thus become of no use. Even supposing them to be carried, and put together, they are not good gabions, as they cannot keep their shape whilst being filled.

In conclusion, I must remark that it appears to be an indispensable requisite in an iron gabion that in addition to its ordinary advantages of durability, portability, and cheapness, it should possess rigidity of form when put together; or else, when being filled, it becomes distorted, gives way to slight pressure, and becomes almost useless as a support to masses of earth.

I am, &c.,

(Signed) GEORGE PHILIPS, Lieut. R.E.,
Assistant Instructor, Field Works.

Report of Experiments Made by Firing 32-pdr. Guns with Charges of 8 lbs. of Powder, to Test the Value of Different Kinds of Revetments for the Embrasures of Siege Batteries.

Royal Engineer Establishment, Chatham, March 29th, 1858.

These experiments took place in an elevated battery constructed for the purpose in the middle of December, 1857, on the low ground in advance of St. Mary's Guard-house and Drawbridge, on the extreme left of Chatham lines.

It consisted simply of 2 gun-portions, with the regular interval of 18 feet between the embrasures, and 2 extreme half-merlons. The interior slope was revetted with gabions. The right embrasure (No. 1) had its right cheek revetted with 9-feet fascines, and its left cheek with Sergeant Major Jones's iron-band gabions crowned with a fascine. The left embrasure (No. 2) had its right cheek revetted with Captain Tyler's sheet-iron gabions, crowned with a fascine; and its left cheek was revetted with the common brushwood-gabion, also crowned at top with a fascine. The sole of each embrasure was made according to the rule of the Establishment, viz., 2 feet wide at the neck, and 3 feet wide at a distance of 5 feet from the neck. The slope of each of the cheeks of both embrasures was the same, viz., it had a base of one-eighth of the height, at the neck, running regularly out to a slope of about 40° at the last gabion.

It should be stated here that in consequence of the battery having been constructed a little more than three months, and of the very dry weather that had taken place generally before these experiments took place, that the brushwood-gabions, and also the fascines, were very dry and brittle, particularly the withes of the fascines; and it is considered that as the embrasures of siege batteries, generally speaking, are only constructed when intended to be required at once, it was hardly a fair test, in the present case, for the brushwood-gabions and fascines.

It should also be stated that the pickets of Sergeant Major Jones's gabions had been previously in use, as such, for about two years, and had been made of old wood, and that the bands were old; also that the sheet-iron gabions used, which were five in number, were three old ones, fastened with wire, in holes punched for the purpose, and two new ones, with the brass eyelet holes lately added to this pattern of gabion, for the fastening wires to be passed through.

It ought to have been stated before that there were five gabions in the revetments of the cheeks of the embrasures, including the one at the neck.

The guns, which were 32-pdrs, of 56 cwt., and 9 ft. 6 in. long, were mounted on siege carriages, and were fired with a charge of 8 lbs. of powder. They were fired alternately to the direct front of the battery, and obliquely to the right and left with the axis of the gun nearly parallel to the cheek of the embrasure.

15 rounds were fired from each embrasure. The observed effects of each round are given at the end of this Report; and the general effects are as follows:

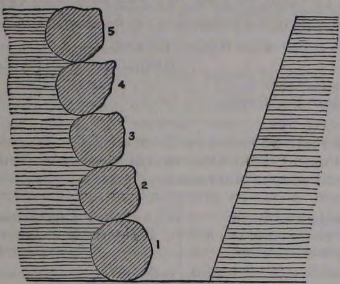
Right cheek of No. 1 Embrasure, revetted with fascines.

The first round blew off a withe, and each succeeding round destroyed some more, until, at the 7th round, the withes of the three or four lower courses of fascines were entirely destroyed. This caused the brushwood to incline inwards, and hastened the destruction of the revetment to a very great extent; it was bodily loosened at the 14th round, and blown away at the 15th round.

Left cheek of No. 1 Embrasure, revetted with Sergeant Major Jones's iron-band gabions.

The pickets of these gabions were forced by the explosions away from the gun, towards that part of the gabion nearest to the mouth of the embrasure. Many of the pickets were broken, and the bands torn and distorted, more particularly in the 2nd gabion (the one at the neck being counted the 1st) which may be considered as destroyed.

The whole of the gabions, except the one at the neck, were forced by the explosions into the shape shewn on plan in the sketch, in about four or five rounds.



This effect is evidently due to the flexibility of the gabion, compared to the stiffness of the ordinary brushwood-gabion, and was the result of the action of the exploded powder, tending to force the cheek of the embrasure into one smooth surface.

After this effect had occurred, the gabions seemed to have settled down, for they did not alter their shape afterwards; the bands and pickets were however gradually more and more broken and distorted. At the conclusion, No. 2 Gabion was almost destroyed; but Nos. 3, 4, and 5 Gabions, although greatly damaged, still formed a good support to the earth of the cheek.

No. 2 Embrasure, right cheek, revetted with sheet-iron gabions, crowned with a fascine.

This cheek stood the firing the best of the whole. No. 1 Gabion gave way at the fastenings, at the 6th round; but, as this was one of the old gabions, without the improved eyelet holes, this occurrence is not considered as operating against the sheet-iron gabion, which is now supposed to be always provided with the eyelet holes. No. 2 Gabion was much flattened, and a little cracked. The remaining 3 gabions were perfect.

The same effect, as is sketched above for the band-gabions, took place with these, and from the same cause, viz., their flexibility, and the tendency of the explosions to form a smooth cheek to the embrasure. These also appeared to settle firmly in their places after the 4th or 5th round. No. 1 Gabion, having given way at the fastenings, protruded about 6 inches into the neck of the embrasure, and prevented the gun being fired for the remaining rounds as close to the other gabions as it could otherwise have been.

No. 2 Embrasure, left cheek, revetted with brushwood-gabions, crowned with a fascine.

This cheek did not stand well. The second gabion was blown open, and the earth fell out of it at the 10th round, and at the termination of the 15 rounds the remaining gabions in front of No. 2 were greatly bulged and slightly torn, and did not form a good support to the earth. The gabions were, however, all very dry and brittle.

The fascines, crowning the cheeks revetted by the sheet-iron, the iron band, and the brushwood-gabions, were all blown away by or before the 6th round; from this it appears to me that sand-bags are much preferable to fascines, to crown the cheeks of embrasures revetted with gabions, and this is also the opinion of the officers who made the Report on the siege-works at Sebastopol (R. E. Professional Papers, vol. vi. page 9).

Should any further experiments be carried on I beg to suggest that the cheeks of gabion-embrasures be crowned with *sand-bags,** that the fascines be bound with *iron wire* instead of brushwood withes, that they be *picketed* down with *pickets with a hooked end,* and that the revetments of the whole of the embrasures be constructed only when wanted, to avoid the chance of the brushwood drying.

GEORGE PHILIPS, Lieut. Royal Eng.

Colonel Sandham, R.E., &c., &c.,
Director Royal Engineer Establishment.

TABLE OF THE EFFECTS PRODUCED BY EACH ROUND OF FIRING WITH 32-PDR. GUNS, THE CHARGE BEING 8 lbs., ON THE CHEEKS OF TWO EMBRASURES REVETTED WITH VARIOUS MATERIALS.

LEFT EMBRASURE, No. 2. Right cheek of sheet-iron gabions, and left of brushwood-gabions.		RIGHT EMBRASURE, No. 1. Right cheek of fascines. Left of band-gabions.	
No. of Round.	Effect produced.	No. of Round.	Effect produced.
1.	The 2nd and 3rd gabions of right cheek slightly indented.	1.	The 2nd and 3rd gabions of left cheek had a picket broken in each; a withe was blown off a fascine in the right cheek.
2.	The 2nd and 3rd gabions of left cheek torn a little at bottom, (gun fired to the left).	2.	2nd gabion flattened; 3rd gabion ditto, in a less degree (gun fired to the left).
3.	The gabions of right cheek flattened (gun fired to the right).	3.	The withes in the three lower fascines destroyed (gun fired to the right).
4.	Fascines crowning both cheeks loosened.	4.	2nd gabion of left cheek much distorted.
5.	Fascine at top of right cheek still more loosened.	5.	Increase of distortion of gabions in left cheek; fascine at top loosened.
6.	No. 1 gabion of right cheek gave way at fastenings and opened slightly; fascine crowning left cheek blown down.	6.	Fascine crowning left cheek blown down; the gabions of left cheek more distorted.
7.	Hardly any increase of effect.	7.	The withes of fascines in right cheek nearly all blown away.
8.	Gabions in left cheek greatly distorted, 2nd gabion being partially blown away at bottom.	8.	No apparent increase of effect.
9.	No increase of effect.	9.	Fascines of right cheek much torn.
10.	2nd gabion of left cheek destroyed.	10.	Gabions of left cheek, especially the 2nd, much broken and torn.
11.	Very slight increase of effect; 2nd gabion of right cheek a little cracked.	11.	Slight general increase of effect.
12.	No extra effect, the sheet gabions apparently having settled firmly.	12.	2nd gabion of left cheek torn open, the others a little more distorted.
13.	Crack enlarged in 2nd gabion of right cheek.	13.	Fascine cheek (right) loosened.
14.	Slight general increase of effect.	14.	Slight general increase of effect.
15.	Ditto ditto.	15.	The fascine cheek blown away and embrasure choked; the gabions in left cheek very much torn and distorted, but, with the exception of the 2nd, sustained the parapet well.

* In the battery at the new range at Woolwich fascines crowning the cheeks of the embrasures have been *tied down* to the gabions with galvanized iron wire, so as to stand well; and this may be also used to *anchor* them.—ED.

PAPER XII.

Notes on the Native Forts in Oude.

By COLONEL HARNESS, C.B., Com. Royal Engineer in India.

All the Indian forts which we have met with have the same general characteristics; their strength consists in a formidable relief, and in the difficulty (perhaps impossibility by means of cannon) of forming a practicable breach, the whole, or nearly the whole rampart being made apparently of an adhesive earth, worked up as clay for bricks would be. The trace, which is frequently a square of greater or less extent, rarely presents any re-entering angles; but at each salient, and at intermediate points where the line is long, solid towers of 50 or 60 feet, and upwards, in diameter, are formed. There are generally two enceintes; the outer consisting of an earthen rampart and ditch, as above described; the inner, of a defensible dwelling, square or rectangular, with towers at the angles, a flat roof, and parapet. But three places that the army has lately met with have each presented an extensive exterior line of works; at Rampoor Kussia, at Ametie, and at Shunkerpoor, from 200 to 250 acres of ground, in some parts very densely wooded, had been enclosed by a line of greater strength, in almost every part, than would be expected to be met with in any field work, and in some places presenting a very difficult obstacle. Thus the exterior ditch of Ametie was not in any place, where the thick thorny jungle would permit it to be approached, less than 20 feet in width, or 15 in depth; indeed a large portion was 30 feet wide, and a part was 30 feet deep.

The points that an assailant may take advantage of in attacking these forts are, the general liability of the few lines that could bear on the approach against the part selected for attack, to be enfiladed, and the total want of bomb-proof cover; these defects would most probably cause the surrender of an ordinary fort, of which the area might be five or six acres, within a couple of days, to an army provided with mortars and howitzers. But, against an army insufficiently provided with these weapons, a fort well defended might hold out for several days; approaches against the works would be necessary, and perhaps a regular descent into the ditch, and a heavily charged mine, to effect a breach, might be required.

Ametie.

The Fort of Ametie is formed by three separate defensive lines. The outer line presents a ditch varying from about 20 to nearly 40 feet in breadth, and from 15 to 30 feet in depth. It had been reported that this ditch contained from 10 to 15 feet of water, which was not the case when the fort was entered on the 11th November, but it is most probably filled to that extent during the rains. At present the only place where the water appears deep is near the principal entrance, on the north of the lake covering a part of the north-east portion of the fort; in other places where the ditch is wet, the water is only two or three feet in depth. There is not a continuous rampart in connection with this ditch, and although the edge of the counterscarp may generally be seen from some part of the works within the ditch, the bottom of the ditch is almost entirely unseen and without flank defence. On the inner side of the lake referred to above, there is an irregular line of earthen ramparts rising from the water; in other places, earthen towers, generally of small elevation, afford positions for guns, but these have been formed at some distance (50 feet or more,) from the edge of the ditch; and round the greater part of the fort trenches have been formed immediately within the ditch, to afford covered positions for musketry. The country is flat, and on the east and north-east, open; it is also open on a part of the south side, but the remainder is covered with jungle more or less thick, which is described as being so thick, on the west and south-west, that a bird could hardly penetrate it; and the officers employed to sketch could not follow the ditch in that part. Within this enclosure, which may be considered to include about 250 acres, is another, comprising about 5 acres; it is formed by an earthen rampart and ditch, presenting on every side, at some former period, a steep escarp and a good relief, but now in some places degraded; and on the west and south-west, the jungle has encroached upon the ditch and escarp.

The innermost enclosure is formed by the dwelling-house and its court-yards; it is only partially surrounded by a ditch, and the exterior wall on the side towards the jungle is weak.

As no roof-cover that would afford secure protection against even $5\frac{1}{2}$-inch shells exists within the fort, the two inner enclosures may be deemed untenable against a well sustained fire of mortars; and it may perhaps be assumed that the garrison did not intend to attempt to defend the inner enclosures, as the only stores of gunpowder found were outside of them. Three such stores were found, and also two mines completely prepared, the hose being laid, one under the causeway across the ditch at the principal entrance, the other about 100 feet from that causeway, under the raised roadway leading from it along the west side of the lake.

The time available for the sketch which accompanies this was very short. It is hoped that the officer left to assist in the demolition of the defences will be able to obtain a more perfect sketch.

SHUNKERPOOR.

At Shunkerpoor about 200 acres of jungle are enclosed by a defensive line, consisting generally of a parapet and ditch of very irregular trace and varying section, but for a length of about 100 yards on the south-west, and of about 500 yards on the west, of a low parapet only; within this enclosure are four forts—the principal fort, situated near the eastern boundary, being the property of Baine Madhoo Sing, and intended, together with the entrenchment round the jungle, to have been defended by him, is known as the Shunkerpoor Fort. The other three are near the Western boundary: the most southerly is the property of Nurput Singh, and the most northerly, of Joograg Singh; and the intermediate fort belongs to Sew Ghoolam Singh.

The exterior entrenchment, on which much work has evidently been recently executed, presents, towards the east, a formidable profile, which diminishes on the north and south sides, where in several places it is easily assailable; and towards the south-west, where it approaches within about 400 yards of the village of Jugutpoor, and also on a part of the west side, the obstacle is insignificant. The jungle within, though thick, is not by any means impenetrable, and it would prevent any proper co-operation of the forts by their fire.

The principal, or Shunkerpoor Fort, comprises about five acres, and the enceinte, consisting of an earthen rampart and ditch, has a good profile on the east and south sides, and on the north near the entrance: but on the north-west the work is much dilapidated, and is at several points accessible to assault without any aid from ladders. There is no bomb-proof cover within it; and the large quantity of powder found distributed in the different rooms, without any adequate protection, permits the assumption that an explosion must have ensued if a few shells had been thrown into this fort.

Of the other three, that near the south-west portion of the outer entrenchment, known as the Jugutpoor Fort, and the property of Nurput Singh, is the only one in a defensible state. It has a single enceinte of good profile in efficient condition, but has no bomb-proof cover, and would not be tenable against a force well provided with mortars or large howitzers.

A sketch of the position, made by Lieutenants Pritchard and Harrison, R.E., accompanies this.

H. D. H.

18th November, 1858.

PAPER XIII.

Notes on the Fort and Entrenchments of Kussia Rampoor, Oudh.

By LIEUTENANT SCRATCHLEY, R.E.

The fort and entrenchments of Kussia Rampoor are situated on a bend or loop of the River Saee; the fort is at the north-west side of this loop, and is surrounded by the southern entrenchments, which enclose the loop to the south, and by the northern entrenchments which complete the enclosure on the other sides; these occupy an extent of ground equal to 200 acres, and are $3\frac{1}{4}$ miles in length.

The interior of the entrenchments is a dense impenetrable bamboo and thorn jungle, through which a number of covered ways, similar to parallels, afford communication; on the outside the jungle grows close up to the works, and in most places extends 500 or 600 yards or more to the front; paths lead through it into the fort, but they are of no use except to the defenders: besides this, a very close and impenetrable abatis, of cut thorn jungle, is to be found close upon the counterscarp of the works, following it in all its sinuosities: the ditch is generally from 12 to 18 feet in depth, but in one or two places the depth is nearly 23 feet; it is 8 to 20 feet in width, and surrounds the whole of the works, except in a few places where a formidable abatis supplies its place.

The profile of the entrenchments is good, the command varying from 10 to 20 feet, the thickness of parapet is from 10 to 18 feet, and they are well able to resist the heaviest ordnance, from the nature of the soil, which is principally clay; in some parts the profile consists of two lines of parapet, separated from each other by a ditch; in others two ditches are to be found.

The interior fort or entrenchment is of the nature generally found in this country, forming a rectangle with circular bastions at the angles, connected by straight curtains, which also have bastions. This fort has a very great command over the surrounding works, and the country around it; it also affords a good defence against an attempt to take it from the south, especially across the ford.

The trace of the entrenchment is very irregular, consisting of circular bastions connected by irregular curtains, every bastion having four or more embrasures for guns. In front of each bastion a low line of parapet for musketry is to be found, and this generally flanks the entrances into the fort before mentioned: the trace, on the whole, is good: it has a few weak points on the river, where the entrenchments close upon it, but these could be strengthened at the very last moment: in fact, if an European force had possession of such works, it could defy any attack except that of a regular blockade to starvation.

The period of the construction of the different parts of the works is of course difficult to ascertain; I should think that all the works, with the exception of the fort and western entrenchments, have been built since the first outbreak of the mutiny; the ditch surrounding them however is very old, and has been deepened in a great many places. The works also have been considerably strengthened and repaired since the rains.

PAPER XIV.

Account of the Bridge of Boats across the Gogra, at Fyzabad.

By LIEUT. COLONEL NICHOLSON, R.E.

The bridge consists of 75 boats of various sizes, ranging from 2,000 maunds* to 300, there being about 11 of 2,000 and 1,500 maunds, and about 20 of a size from 900 to 600, and the remainder of a smaller description.

All these Indian bridges of boats are built on the same principle, the superstructure being precisely similar to that used for pontoons, except that the timber and planks are of larger scantling and thickness; half of this bridge only is however constructed on this principle, as wood was scarce and time an object; the wood was not only scarce but exceedingly difficult to work, so instead of using the large beams, or as they are called here "kurries," in the remaining half of the bridge, bamboos were substituted, and answered admirably. The bamboos can be easily replaced in case of damage, and a boat becoming injured can be removed without disturbing the roadway; so when they can be had, bamboos make a better superstructure than timber. And nothing is simpler than to lay them, no skilled labour is required, the Fellahs are perfectly well able to do the work without assistance from carpenters or blacksmiths. The method of fixing them is merely to tie them to the cross-beams of the boats, first laying kurries lengthwise above those beams, so as to make up the difference between the level of the road and the level of the boat's beams, and thus getting a bearing in three or four places, the boat's beams themselves being supported from below by uprights wedged in between them and the boat's bottom. This ought always to be done to take the bearing off the sides of the boat, and put in on the bottom. The bamboos are placed close together; those used by us were certainly of a large size; and with ease, with an interval of 10 feet between the supports (in a trial) bore two very large elephants standing side by side, that is to say, the two elephants stood in a space 12 feet wide and 10 long; but I believe that much smaller bamboos, of course in greater numbers, and with $1\frac{1}{2}$-inch planking, would sustain any weight likely to pass across a bridge of boats, with bearings of about 4 feet. The bamboos we used were straightened by bending the crooked places in each over a slow fire, and soaking them in oil, until they could be bent without cracking; rendered thus more pliable, they were fixed in a straight position until they became cool and dry. The extreme bearings of the kurries were 10 feet, their dimensions were $9'' \times 4''$, or $8'' \times 5''$, and they averaged 20 feet in length. The roadway has five kurries in its width and is 12 feet broad, so that they are about 2′ 2″ apart. Where we used kurries the planks were 3″ thick, but over the bamboos it was only necessary to place planks of half that thickness.

The bridge is 470 yards long, piers being constructed at each end to carry the roadway over the shallow water. The stream set diagonally across the river, so that considerable difficulty was experienced in bringing each boat into its proper position.

* The maund is equal to 80 lbs., and 28 maunds to 1 ton.

The boats are all at different distances apart, varying according to their buoyancy and strength; between the large boats, and using large kurries, the bays were 10 feet wide, but the smaller boats were only 3 feet apart, using either kurries or bamboos.

Each large boat was moored by 3 anchors a head, each small boat by two, and all had one anchor astern. The anchors are of rude construction, formed of two massive cross-pieces of timber pointed at each end, into these are fixed upright pieces of bamboo, one end of each in the wood, and the others fastened together, thus forming a sort of hollow pyramid; to the bamboos is fastened matting which serves to retain the koucha, with which the anchor is weighted. The cables are made entirely of grass twisted together on the spot, and are very strong and well adapted to the purpose, but would not stand any friction.

The bridge was commenced on the 15th October, and progressed very slowly, owing to the difficulty we experienced in collecting boats and material, but it was ready for the passage of troops by the 21st November, or the day before the arrival of Brigadier Taylor's Force.

When the work was first commenced it was known that large bodies of the enemy were on the opposite shore, and that they would annoy us directly we began. Our force was not large enough to enable us to occupy that side, so that it was necessary to select such a spot in the river as would enable us to work out of range of any batteries the enemy would probably erect; advantage was therefore taken of a wide breadth of sand between the river and the sound ground, on the northern side, on to which the enemy were not likely to come, and which, if they did, would have been commanded by our guns.

As it turned out, it was well this spot was selected, as the enemy lined the edge of the sound ground with works, and brought four or five guns to bear upon the bridge; but though they fired very often, the range was too long for them, and they never succeeded in striking it or injuring the workmen employed upon it.

Before the bridge was quite finished, and to gain as much time as possible, the pier on the opposite side was carried out 50 yards into the water, and the road over the sand was commenced; this was ultimately pushed on by degrees to within 700 yards of the grass, small pickets of about 24 men being posted in breastworks constructed ahead of the workmen, to protect them in case of an attack from the enemy.

When the road had been completed to this point, two 8-inch howitzers and two mortars were placed in position, and everything was ready to pass the Force across.

The accompanying sketch shows the plan adopted by Major General Grant to force the enemy's position.

The Sikhs were passed across the river far above the enemy's works, and the remainder of the Force was collected between the bridge and battery above-mentioned.

These dispositions were finished before dawn, and just as day broke the Sikhs advanced from the bank of the river, and, taking the enemy by surprise, drove them from their entrenchments. Directly the firing was heard the General advanced with the main body, and the enemy fled in all directions: he pursued them for about ten miles, and took all their guns, and thus closed the operations on the Gogra.

LOTHIAN NICHOLSON, Lieut. Col. Royal Eng.,
Com. Eng. with Sir Hope Grant, K.C.B.

To Colonel Harness, C.B., Royal Engineers,
Com. Royal Eng. in India.

PAPER XV

Notes on different kinds of Labour.

By CAPT. TILLY, R.E.

As the Corps has often been called upon to act under unusual circumstances, and with various means, apart from ordinary routine, perhaps a few Notes on Excavation, made in the course of throwing up some heavy batteries by means of different kinds of labour, may afford sufficient data, as a rough guide in future operations, when duty points in that direction.

In the summer and autumn of 1856, the works required in constructing the New Practice Range in Plumstead and Erith Marshes, near Woolwich, were commenced. The greater part was executed by contract, but the batteries and a large earthen work were intended to be constructed by Sapper labour, and the 5th Company of Royal Engineers supplied the working parties.

During the progress of the excavations it was found that the force of Sappers was not strong enough to complete its task within the specified time. Assistance was therefore derived from the contractor's "Navvies" who had been employed in excavating the boundary ditch of the Range. A gang of convicts from the hulks off the Royal Arsenal was also permitted to throw up a mortar battery situated within the Old Range, being placed under a safe guard.

Thus there were three distinct descriptions of labour in excavation brought under comparison, by means of the Sapper, the Navvy, and the Convict, using the same sort of tools, and working in the same kind of soil—a stiff clay.

After the excavations of their respective batteries had been completed, they were measured, and the results were as follows:—

The Navvy excavated at the rate of	8	cubic yards a day.	
The Sapper	,,	5	,,
The Convict	,,	2	,,

an *average* of 8 hours being taken as the working day, though the navvies worked 10 hours, and the convicts only 5 hours a day.

The working pay of the respective labourers was for

	s.	d.
The Navvy.	3	6 a day.
The Sapper.	1	0 ,,
The Convict. . . , . .	0	$1\frac{1}{2}$,,

The cost therefore of excavation by means of these three kinds of day labour, calculating for the *whole time* per diem during which each man worked, was:—

$4\frac{1}{8}$ pence per cubic yard by		Navvy labour.	
$2\frac{2}{5}$,,	,,	Sapper	,,
$\frac{3}{8}$,,	,,	Convict	,,

and the time taken by each party shewed that

The Navvy would excavate	100	cubic yards in	100	hours.
The Sapper ,,	100	,,	160	,,
The Convict ,,	100	,,	400	,,

or, reckoning by days, the working time being, as before,

The Navvy would excavate	100	cubic yards in	10	days.
The Sapper ,,	100	,,	20	,,
The Convict ,,	100	,,	$66\frac{2}{3}$	,,

On the face of these calculations convict labour would appear to be the cheapest; but, as time is money, and the expense of the plant, of feeding, clothing, and lodging, and, in the case of the convict, of *guarding*, must not be neglected, it would be found in the end to be the dearest; and the free labour of the navvy must be admitted to be the best and the cheapest.

Where expedition is required, the labour of the navvy would be of the utmost value. Let us suppose, for instance, that some massive earthworks were intended to be thrown up at one or two of those points which it is considered desirable to occupy for the defence of the metropolis, and suppose one of them to require a "deblai" of 5,000 cubic yards. One hundred navvies would complete the excavation in 5 days, the same number of Sappers would require 10 days, while the convicts would linger over the job for 33 days. If the enemy were advancing it is almost needless to say which labour would be of the greatest value.

Of course the Sapper is, in such a case, in his right place when he is fixing profiles, forming slopes and embrasures, laying down drains, &c., and attending to all matters requiring skilled labour. It is not supposed that convicts would be employed, as a general rule, on this kind of work, as there are many other questions involved; but the calculation is interesting for the sake of showing the strong contrast between free and forced labour.

Besides being employed on day work at the New Range, the navvies also undertook task work, and excavated from 12 to 14 cubic yards a day. Some giants, for a wager, have been known to throw out nearly 20 cubic yards in one day. These men, in order to renew their strength, eat and drink in large quantities four and even five times a day.

The quantity excavated by the Sappers is considered to be very fair, and quite as much as could be expected from a mixed body of mechanics. Two men of the party, better accustomed to the work than their comrades, worked as well as an average navvy. But it is not to be expected that Sappers can compete in mere excavating with men who have handled nothing but the "grafter" and "flying tool" from their boyhood.

With regard to the convicts, all that can be said is that even with the inducement of pay, and by granting an extra allowance to the keepers, upon completing certain tasks, convict labour still remains *forced* labour. Sometimes an improvement results from employing them in gangs on heavy work, as in throwing in masses of concrete, or making large excavations, and by stirring up a spirit of emulation between the different gangs; but it must be admitted that it is still unprofitable labour resulting from inevitable causes.

G. S. TILLY, Captain, Royal Engineers.

Cape Town, March, 1858.

PAPER XVI.

REPORT ON THE LAYING DOWN OF THE ELECTRIC TELEGRAPH AT CANTON.

BY MAJOR FISHER, R.E.

1. The Major General Commanding having decided to have electric communication between Head-quarters and the landing-place, with an intermediate station at the East Gate, I was instructed to carry out the work.

2. The Head-quarter Terminus of the line was arranged to be in the rear of the Royal Artillery Barracks, half-way between the General's quarters and the Head-quarter office: that at the landing-place was close to the office of the Senior Naval Officer; and the East Gate Station was in the enclosure in rear of the Royal Artillery Guard. Huts were to be built for the telegraph offices at Head-quarters and at the East Gate, and an existing building was to be fitted up for the purpose at the landing-place. The course of the wire between Head-quarters and the left extremity of the cantonments was to follow the contour of the hill, running up into the city wall at that point, thence to the landing-place it was to be laid under-ground along the top of the wall, at a depth of 1 foot below the surface and close to the banquette or step, for the sake of protection from accidents.

3. A working party of 40 men of the Royal Engineers and 500 of the Line was furnished at 6½ A.M., on the 26th of April, 1858, to work half a day. It was intended to open a communication between Head-quarters and the East Gate by the evening of that day, but heavy rain came on, and the party only worked till 9 A.M., completing the trench as far as the north-east angle, but laying no wire; on the following day 40 men of the Royal Engineers and 300 of the Line were employed, of whom the Engineers and 150 of the Line worked for 8½ hours, and the remaining 150 only 4½ hours. The wire was well laid and the trench filled in by 6, P.M.

4. The length of wire laid down was 3 drums and about 300 yards, the measured distance being about 3,500 yards. At this rate of working, one mile of wire would be laid down in one day of 8 hours, by 25 of the Royal Engineers and 200 of the Line.

5. I had observed, when at Chatham in charge of the Electric Telegraph School, that no batteries had been sent out with the telegraph stores for the China expedition, but I was informed that the instruments sent were *magnetic*, and I believe that they were intended to have been so. However, on unpacking the instruments, they were found to be the ordinary single needle instruments; consequently batteries had to be furnished.

6. Sulphuric acid was obtained from the Medical Department, and zinc was purchased in the city, but no copper could be procured in Canton, though there appeared to be a quantity of brass. A portion of the silicate of soda had been sent up from Hong Kong in old powder barrels, with copper hoops. These were replaced by iron ones, and cut into lengths to fit the cells, which were glass tumblers. A battery com-

posed of 12 of these cells was found sufficient to send messages from Head-quarters to the landing-place, but the current was rather weak, the copper plates being narrow and affording too small a surface, (only 2½ inches by 1 inch).

7. The line was opened on the 5th of May, 1 Sergeant and 1 Sapper being stationed at Head-quarters, and 1 Corporal and 1 Sapper at the landing-place.

8. The station at the East Gate will be opened as soon as the copper can be procured for the battery. It will in future be supplied by the Navy.

9. The readiness with which a mistake, such as the omission of sending out batteries, can be rectified, as well as the simplicity of the works, and the ease with which they are repaired, would appear to be an argument in favour of the use of the ordinary single needle instrument for field service in preference to the magnetic.* The facility with which batteries can be constructed and the materials procured in any part of the world is very great. The readiness with which additional power can be given by increasing the number of cells if the line should get defective, either from bad joints, or accidents occurring, such as the cracking or melting of the gutta-percha (which happened frequently in the Crimea), is, I think, another point of superiority. The plates of the magnetic instruments require great nicety in fitting, and the instrument-case is not capable of extension, so as to contain additional plates, at all events without considerable trouble.

10. The much greater ease with which the single needle is read, places it within the power of almost any man to send and receive messages after three weeks' instruction, whereas, whilst in charge of the Electric Telegraph School at Chatham, I have known men instructed in the use of both the double and single needle, fail altogether in attempting to learn the magnetic system. The advantage of rapidity of reading is on the side of the single needle in the proportion of 10 to 7.

11. Had magnetic instruments been sent out to China, there would have been found, in two Companies of Royal Engineers, only four men capable of using them ; whereas there are nine who are able to use the single needle.

12. The length of time which it takes for a man to go through the course in the Telegraph School at Chatham (about 5 months), renders it unlikely that any considerable number will attain to much skill in the use of the magnetic instruments, though a great number are instructed in the use of the two others. The double needle I put out of the question for field service, as it requires a double length of wire, the advantage of increased rapidity (16 to 10) not compensating for this, and indeed not being necessary, unless a very great number of messages are sent, as on a railway line.

13. As regards the carrying of the batteries, which seems to be the only objection to the single needle instruments, it does not appear to me to make much difference, when the wire, instruments, &c., have to be carried, whether the batteries are carried in addition, since battery power for six stations, sufficient for any distance likely to be required, may be put up so as to occupy no more space than a single drum of wire.

A. C. FISHER.

* Magnets are however successfully employed for this purpose in Ireland and in Italy, and it is probable that by increasing the thickness of wire in the coil, and making the magnet itself more powerful, an instrument may be constructed which would be very convenient for military purposes, and efficient even when the covering of the wire is very defective. In cases in which the magnet has been given up in favour of the Voltaic battery, the change has been made, not on account of difficulties of insulation, but because the signals could not be sent with the same rapidity as they could by means of the battery ; and this would be a comparatively unimportant objection to its use for military purposes.—Ed.

PAPER XVII.

Description of the improved Metallic Gabions, invented by Captain Henry Tyler, R.E., and manufactured by Messrs. Carter and Co., of Foundry Street, Red Bank, Manchester.

By LIEUT. GENERAL SIR C. W. PASLEY, K.C.B.,
Royal Engineers.

1. Captain Tyler's gabions were originally supplied in the form of flat plates of iron, either galvanized or plain, or served over, when hot, with boiled oil, 6 feet 3½ inches long and 2 feet 9 inches wide, to the ends or short sides of which sailmakers' eyelets were afterwards fixed in corresponding pairs, and being brought together until they met in a cylindrical form, the several pairs of eyelet holes were connected by fastenings, so as to make a metallic gabion, 2 feet in diameter, and 2 feet 9 inches high.

2. Having observed, in the first trials of these gabions, in December, 1857, that the metal of which they were made was so brittle that it broke whenever the bottoms of them came in contact with any hard substance, such as a piece of brick or stone, and having further discovered that galvanized iron was a perishable material which lost its original strength in the course of a few years,* it occurred to me that tin would be a much better material for a metallic gabion; but having reason to doubt the quality of the common tin of commerce, I applied to Messrs. Carter and Co, of Manchester, who recommended the use of the best iron, scaled and cold rolled, and informed me that the bottom and top of the gabion might be effectually secured by strips of the same metal two inches wide, doubled and folded over the whole length of the long sides of the plate, and beaten down upon those sides, in a manner termed "shoeing" by the workmen, previously to their being tinned.

3. Accordingly, I directed Messrs. Carter and Co. to make plates of the above description, to shoe them in the manner proposed, and to rivet together the three thicknesses of the plate and shoes at intervals of 5 inches.

4. The figure at the bottom of the annexed drawing is the plan of Captain Tyler's improved metallic gabion, laid flat, with its long sides reinforced, by shoeing them in the manner that has been described. Five pairs of brass eyelet holes, 1,1, 2,2, 3,3, 4,4, and 5,5, each half an inch in diameter, within a circular rim a quarter of an inch wide, are fixed to the ends or short sides of the plate, at the central distance of 1 inch from the said sides. Two round holes, I, II, each 1¼ inch in diameter, are punched through the centre of the plate, in the same alignement as the eyelet holes 3,3,of which the first, I, is to be cut at the central distance of 8 inches, and the second, II, at the central distance of 2 feet 6 inches from the nearest side of the plate. The extreme eyelet holes, 1,1, and 5,5, are to be fixed as near to the long sides of the plate as the shoes will

* Part of Captain Tyler's gabions, and all Sergeant Major Jones's, that were tried on this occasion, being made of iron not galvanized, were covered with rust.—C. W. P.

permit, with the others at equal intervals; and the whole are used for lashing the corresponding pairs of holes together, so as to form a cylinder when the plate is to be made into a gabion for service.

5. Two additional eyelet holes, (marked 6,6,) are fixed as close to the long sides as the shoes will permit, and at the same central distance of 2 feet 6 inches from the near side of the gabion as the round hole II. They are for lashing the tools to the upper side of the plate when formed into a gabion. One eyelet hole would suffice for this purpose, but another is made because it is most convenient that *either* of the long sides of the plate may be the top or bottom; and in this state the plates are tinned with great care in the usual manner.

6. Considering that paint, which had preserved the old English tin pontoons from corrosion by salt water, in the bridge formed by Captain, now Major General Piper, over the Bidassoa. in 1813, and had also preserved them for several years in our own practice in the brackish water of the Medway, would be necessary, for protecting the tinned plates when made into gabions, so as to render them serviceable in successive batteries or saps, in the same siege operations, or when laid up in damp stores, we determined to paint them, but did not decide upon the colour until we had made several trials, in which we found that red could not be distinguished from black except by daylight, whereas, even in bright moonlight, white could be seen at a short distance by the working parties, but not by the enemy; and therefore we directed Messrs. Carter and Co. to have all their plates served with two coats of the best *white* paint.

7. It having been found, on trial, that the former mode of lashing the shovels rendered them top-heavy, we decided upon lashing them with the helves uppermost, and with the pans standing about two or three inches from the ground, to prevent the iron from striking when the gabion was set down. For this purpose, it proved necessary to bore a hole $\frac{3}{8}$ths of an inch in diameter, through the middle of the helve of each shovel, in a direction parallel with the top of the pan, and 18 inches above it.

8. A couple of plates are formed into two gabions by one man, provided with ten lashings of Newall's patent wire cordage, each fifteen inches long, $\frac{1}{8}$th of an inch in diameter, and weighing $\frac{1}{4}$ of an ounce; besides two lashings for the tools, of $\frac{3}{4}$-inch rope, nearly $\frac{1}{4}$ of an inch in diameter, each 18 inches long, and weighing rather less than $\frac{1}{2}$ an ounce. All the lashings must be served, and the tool-lashings moderately pointed at the ends.

9. In this operation, the workman lays his plates flat on the ground, and after turning over the ends till they meet, he lashes the five corresponding pairs of eyelet holes together, by taking one round turn through both, and tying the ends together by a reef knot commencing with the centre holes 3,3, as the most convenient; and as their shape may be rather irregular, he forces them into a cylinder of two feet in diameter, by pressing down the ties. This is essential, because each workman's task, in the flying sap, is 4 feet, and at smaller intervals they would be too crowded. He then sets his gabions on end, about 1 foot apart, with the ties to the front, and the pair of round holes, I, II, of each gabion opposite to one another, with the holes I in front. He will then take post between his gabions, a little to the rear, in readiness to secure the tools, by lashing a pickaxe to one and a shovel to the other. Both gabions may be put together in four minutes, at the rate of two minutes per plate. At this period, if the pair of holes of one of his gabions should not be near to his right or left side, as it ought to be, he must turn it upside down, which will set it to rights.

10. Besides the above-mentioned lashings, every man must be provided with a couple of pickets of ash or hazel, with the bark on, each 2 feet long and not exceeding $1\frac{1}{8}$th of an inch, nor less than $\frac{7}{8}$ths of an inch in diameter, which he must run through the round

holes I, II, in each of his gabions, until their ends project equally, that is 3 inches in front and rear,* after which he will secure the tools in the following manner, which may be done in less than a minute.

11. Placing the iron part of the pickaxe on the top of one gabion, with the broad edge to the front, parallel to the picket below, and with the helve downwards, he passes one end of his lashing through the eyelet hole 6, round the upper part of the helve and over the top of the gabion, and makes it fast to the other end by a reef knot.

12 He then passes the other lashing through the hole in the helve of the shovel, until the ends project equally on each side, after which he sets up his shovel in the other gabion, with the convex side of the former coinciding with the concave side of the latter, and the helve opposite to the eyelet hole 6. He then passes one end of his lashing through the said eyelet hole, and over the top of the gabion, and back again, and makes it fast to the other end by a reef knot, hauled taut, which raises the pan of the shovel, to prevent it from striking the ground, as was before mentioned.

13. Such is the manner in which Captain Tyler's improved metallic gabions would be arranged at the Engineer park, in readiness for the men of the working parties who are to carry them to the trenches, where they should, in the first place, be deposited at the reverse of the trench forming the first parallel, previously opened and completed to its proper width, in readiness for the working parties that will be ordered next night or the night following, according to circumstances, for commencing the second parallel, which is always done by the flying sap.

14. When the whole of the working party are ready behind their respective gabions, and the order is given, each man takes hold of the pickets, which he grasps in his hands, and lifts the gabions, one under each arm, and carries them like a pair of pails or buckets, whilst the helves of the pickaxe and shovel are immovably jammed, in the angles between the pickets and the insides of their respective gabions, so that they cannot possibly clatter or make any perceptible noise. In taking their gabions up, the mens' arms must be inside of their pickaxes, as in the upper figure of the annexed drawing, which represents a soldier of the working party on his way to the trenches, after the order to march has been given.

15. Thus all the defects of Captain Tyler's original metallic gabions have been removed, a very perfect having been substituted for a defective and perishable material, their tops and bottoms, which were formerly brittle, having been so much strengthened by the shoes, that a smart blow of a carpenter's hammer, or of a poker, produces no effect upon them.

16. Such being the case, it will be evident that they are infinitely superior to Sergeant Major Jones's gabions, each consisting of 8 iron bands and slots, and 12 pickets, 3 feet 6 inches in length, making 20 pieces in all, besides the bearing pickets, which are common to both. In putting the latter together, a circle, 2 feet in diameter, must be traced on the ground, round the circumference of which the pickets must be driven, and the bands or hoops forming the web must be put together, and interwoven between them, in successive courses, breaking joint from the bottom upwards. In this tedious process, the same number of men, never less than two, must be employed, as in making a common gabion, and the ground, if uneven, must previously be levelled, which will either waste time or require an additional man.

17. From what I have seen myself of these band and picket gabions, I do not think that two men will be able to put together a couple of them in less than a quarter of an

* At first we used ash pickets of the above length, turned in a lathe, and 1 inch in diameter, like the trenails of shipwrights, but we rejected this expedient on finding that the gabions always slipped off from pickets of this description.—C. W. P.

hour, whereas one man will put together seven of Tyler's gabions with ease in that period, allowing 2 minutes for each, as before mentioned, in every sort of ground, whether level or not; and this operation is so simple that any man may learn it in ten minutes.

18. Since I published the second edition of Part I of the "Rules for Conducting the Practical Operations of a Siege," I am of opinion that the men of every working party should always take their arms with them, slung behind their backs, having the slings in front, over their right shoulders, and under their left arms, with the butt of the piece downwards, and a few rounds of ball cartridges; and that they should never go without them under any circumstances. The weight of a couple of Captain Tyler's gabions is 56 lbs., to which, adding for a pickaxe $10\frac{1}{2}$ lbs., for a common sap-shovel $5\frac{1}{2}$ lbs., for 2 bearing pickets 1 lb., and for 14 lashings $\frac{3}{4}$ lb., the whole weight to be carried by every soldier of the working party will be $73\frac{3}{4}$ lbs., which the long handled shovel, if used in preference, will only increase to $75\frac{1}{4}$ lbs.

19. To carry materials in hand-barrows, with two men to each, for moderate distances, in successive trips, alternately loaded and empty, has often been necessary in civil as well as military works, and is never considered a hardship; and every one who has seen Tyler's improved gabions, arranged in the above manner, and tried their weight, admits that a man could carry a couple of them with much greater ease than one common gabion of brushwood, weighing not less than from 36 to 40 lbs. on his left shoulder, and a shovel or pickaxe in his right hand, as was done in the Crimea. But the same remark applies even to the metallic gabions of 28 lbs., which may be carried with greater ease in pairs than singly, from the Engineer park or depot to the trenches, in which, if the distance be so great as to require it, the men should be halted for about five minutes, to set down their gabions, and stand at ease, at intervals of perhaps not less than 400 yards, in readiness to take them up again and carry them in the same order to their destination; whereas, if each carried only one gabion, they would, in case of any stoppage, throw them down in confusion, with the risk of losing them in the dark, unless painted white.

20. Besides this confusion, the arrangements adopted in the Crimea, owing to the great weight of common gabions, doubled the strength of all the working parties, and thereby harassed the whole army unnecessarily, whilst one half of those parties, though liable to be exposed to the enemy's fire, were obliged to be idle, as they had not room to work without cutting one another with their tools.

21. Having ascertained that no military stores are forwarded to India by the overland route, so that these gabions, if approved, must be sent by sea to Calcutta, and from thence by water carriage up the Ganges, and other navigable rivers, to the seat of war, I requested Messrs. Carter and Co. to give me a tender for 50 packing cases, to contain 40 plates each, instead of the original arrangement, which would have required ten times the number of lighter ones. The 40 plates are to be packed as close together as possible, which will require a space of about 6 feet $4\frac{1}{8}$ inches, by 2 feet $9\frac{3}{4}$ inches, in the clear, within each packing case, of which the top and bottom will be 6 feet $6\frac{7}{8}$ inches in length, and 3 feet $\frac{1}{4}$ inch in width, consisting of longitudinal 1-inch fir boards, with 3 transverse bars riveted together, like the ledges of pontoon chesses, of 3 inches by $\frac{7}{8}$-inch scantling, extending the whole width of the case.

22. In respect to the lashings and bearing pickets, described in paragraphs 8 and 10, for putting the 40 plates together as gabions and carrying them, we found that they could not be stowed away in the same packing cases without adding inconveniently to the bulk and expense of the latter, and therefore they were ordered in London of several tradesmen. The quantity necessary to complete each of the 50 sets, consisting

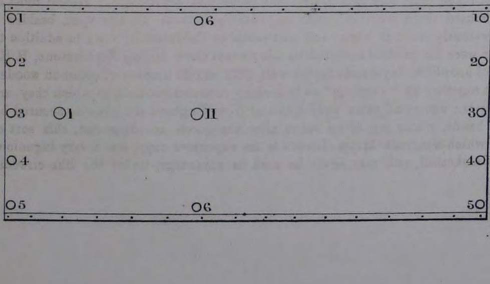
of 220 wire lashings, 90 rope lashings, and 45 pickets, allowing a small proportion of spare ones of each sort, was made up into a compact round bundle, with the lashings in the centre, 2 feet high and 3 feet in circumference, which was packed very conveniently in a canvas bag, wide enough to admit them with ease, and 2 feet 6 inches high, served with Stockholm tar and horse grease, and fastened at top by a piece of cord drawn through 6 brass eyelet holes. The bags are to be painted from No. 1 to No. 50, in large letters, to correspond with the 50 packing cases numbered in the same manner. The plates made up into gabions, together with the tools for the use of the working party to be employed in carrying them, will previously be arranged in pairs at the Engineer park, in the manner described in paragraph 13, where the helves of all the shovels will be bored as directed in paragraph 7, with holes for the lashings, which are too small to weaken them.

23. Messrs. Carter's original tender, forwarded to me 3 months ago, for supplying 2,000 of Captain Tyler's improved gabions, delivered at Manchester, amounted to £1,025 for the plates, shoes, eyelets, &c., and to £162 for putting them together, providing for materials and workmanship of the best quality, for which they themselves, as iron and tin manufacturers, were responsible, always appeared to me to be reasonable; but the tender for painting the plates, given in at the same time, and that for the 50 packing cases, given in afterwards, when they were required to deliver the whole at the East India Docks, London, having been charged by the painter and carpenter they usually employed, at higher prices than those of the best workmen in London, as I found by enquiry, I objected to these items, which were reduced accordingly to rates affording a fair profit on good workmanship; and they agreed with me, that instead of sending them from Manchester to Goole, and from thence by sea to London, as was at first contemplated, the best and safest mode of conveyance, though rather more expensive, would be by the fly-boats of the Grand Junction Canal Company, which would take them on board at Manchester, and deliver them at the East India Docks, alongside of some ship chartered for conveying military stores to Calcutta.

24. At the end of this Paper I have annexed an abstract of Messrs. Carter and Co.'s amended tender, together with those of the tradesmen who are to supply the bags and their contents, all of approved quality and on reasonable terms, amounting to £1,549 8s. 9d., which is at the rate of 15s. 6d. a piece, minus a very small fraction (rather less than a quarter of a farthing); and considering that they dispense with all skilled labour, are of imperishable materials, and are lighter and more portable than any former gabions, they are well worth the price above stated. They were proposed by Captain Tyler to the Inspector General of Fortifications, through the then Deputy Adjutant General, for trial in the practical siege operations of the Corps at Chatham, in August, 1853, before the war with Russia broke out, and several thousands of them were afterwards made at his request for the Crimea, and, if sent out immediately, would have arrived in time for the latter part of that protracted siege; but, unfortunately, they did not reach their destination, until the place had capitulated. Hence most of the gabions used there were of common brushwood, made on the spot, besides a number previously made at Varna and sent round to Balaklava by sea; in addition to which there were the gabions invented by Lieutenant (now Major) Elphinstone, R.E., composed of hoop-iron hay-bands for the web, with an odd number of common wooden pickets put together by "randing," as in making common gabions, to which they are much superior; and as all other packages sent from England are likewise secured by hoop-iron bands, which are of no value after the goods are delivered, this sort of gabion, of which Sergeant Major Jones's is an expensive copy, was a very ingenious and useful makeshift, and may again be used to advantage, under the like circum-

THE METALLIC GABION.

INVENTED BY CAPTAIN HENRY W. TYLER, R.E., IN ITS IMPROVED STATE.



C.Moody Lith. London

stances. I shall conclude by remarking that Elphinstone's gabions were quite original, as he had never heard of Tyler's, which were of prior date, a matter of little importance in other respects, but not to be depreciated, so long as officers are to be found whose object, in bringing forward new inventions, is not their own private profit, but the benefit of the government or that of the public.

ABSTRACT OF THE TENDERS FROM MESSRS. CARTER AND CO., AND OTHERS, FOR THE SUPPLY OF 2,000 OF THE METALLIC GABIONS, INVENTED BY CAPTAIN HENRY W. TYLER, R.E., TO BE DELIVERED AT THE EAST INDIA DOCKS, LONDON.

Messrs. Carter and Co's. Estimate for

	£	s.	d.		£	s.	d.
2,000 plates with shoes, eyelets, &c.	1,025	0	0				
Putting the same together.	162	0	0				
Painting ditto.	134	0	0				
Packing cases for ditto.	50	0	0				
Conveyance of ditto to East India Docks. . . .	38	0	0				
				=	1,409	0	0

Messrs. Newall and Co's. Estimate for

	£	s.	d.		£	s.	d.
11,000 wire lashings, 15 inches in length and ⅛th inch in diameter (served at the ends). . . .	110	0	0				

Mr. C. Good's Estimate for

	£	s.	d.		£	s.	d.
4,500 rope lashings, 18 inches in length and ¼-in. in diameter, served at the ends, at 4s. 6d. per hundred.	10	2	6				

Mr. G. G. Saggers's Estimate for

	£	s.	d.		£	s.	d.
2,250 pickets, 2 feet in length and 1⅛ inch to 1¼ inch in diameter, of ash and hazel, at 12s. 6d. per hundred.	14	1	3				

Messrs. Walker's Estimate for

	£	s.	d.		£	s.	d.
50 sacks, 36 inches in circumference and 30 inches in depth (dressed and numbered, at 2s. 6d. each)	6	5	0				
				=	140	8	9
					£1,549	8	9

C. W. PASLEY.

NOTE.—Since writing the above, I have obtained from Messrs. Tupper and Co., a gabion made of good galvanized iron, and formed like those above described, excepting that the long sides are not shod, 2,000 of which they offer to deliver in any part of London for £658 6s. 8d., less 2½ per cent. discount. The price is thus reduced to 6s. 5d. each, and the edges of this gabion resist smart blows of a poker without being injured.—C. W. P.

PAPER XVIII.

Memorandum on the Three Passages of the River Ganges, at Cawnpore, during the Rainy Season of 1857, by the Oude Field Force, under Command of the late Major General Sir Henry Havelock, K.C.B.

By MAJOR CROMMELIN, Bengal Engineers.

The Oude Field Force crossed the River Ganges at Cawnpore, during the rains of 1857, on three different occasions—1st. At the latter end of July, when it first entered the Oude territories with the object of relieving the Lucknow Garrison; 2nd. Early in August, when, after having been proved to be too weak to effect the above object, it re-crossed the river to defend the Cawnpore entrenchment, which was threatened by two bands of rebels; and 3rdly—When it again proceeded to the relief of the Lucknow Garrison, in September, after having been reinforced. These three Passages I purpose describing separately and in detail.

First Passage—20th to 28th July, 1857.

On the re-occupation of Cawnpore, after the expulsion of the rebels, General Havelock gave orders that arrangements should be at once made for passing his troops, (consisting of about 1,500 men of all arms, and 13 field guns) over the river; and that a small entrenchment should be prepared for a detachment of about 300 men that he proposed to leave at Cawnpore, for the protection of the town and cantonment.

The site for the entrenchment, (which, be it remembered, was only intended to answer a temporary purpose), was fixed on the bank of the river (see accompanying Plan), close to the Ganges Canal, and was selected for the following reasons:—1st. because it was the highest ground; 2nd. because it was within convenient distance of the town and bazaars; 3rd. because it contained a convenient number of buildings that would answer as cover for sick and wounded men and stores; and lastly because it covered the passage of the river along the route that appeared most feasible for retreat, and at the only place where there was any chance of succeeding, during the floods, in the construction of any bridge of boats that we might possibly find it convenient to establish.

The original Entrenchment (as shown in the Plan), but which has since been much enlarged and strengthened by outworks, was traced by Lieutenant Russell of the Bengal Engineers. Time would not permit of his insisting upon following a very scientific trace. A defensible position was required urgently and immediately, and he took every advantage of the nature of the ground and of existing cover (in the shape of compound walls and ditches), to effect the desired object. The parapet was everywhere 8 feet high, and varied from 6 to 18 feet in thickness at the crest.

The arrangements for the passage of the river were superintended by Lieut. Colonel Fraser Tytler, Assistant Quarter-Master General of the Force. He managed to collect a great number of boats, of all sizes, in a very short space of time, but was not able to man more than about thirty of them for this operation; although ultimately he succeeded in organizing a Corps of 350 boatmen, which enabled us to succeed with our subsequent more rapid operations. Had this number of boats been sufficient to carry over the whole force, with its guns and equipments, in one or even a few trips, Colonel Tytler would have selected the Magazine Ghat for the place of embarkation, as from thence the boats could have been at once ferried across to the Lucknow Road Ghat. But seeing that the rapidity of the whole operation would depend upon the time that each boat would occupy in completing the double trip, or rather both the forward and return passages; and justly hoping to be assisted by the east wind which usually prevails at that season, (but which unfortunately failed until the last day), he fixed upon the Gora Ghat, nearly opposite the Lucknow Road, as in every respect the best point of departure.

A floating pier was constructed at the Gora Ghat, and a pier-head at the Lucknow Road Ghat, and several of the boats were fitted with decks or platforms for carrying guns, ammunition, and Commissariat carts and cattle.

The passage commenced on the 20th of July; but, owing to the existence of shoals, velocity of the current (which in several places exceeded six miles per hour), and the width of the river (1,500 yards) was not completed until the 28th of the same month. It must be borne in mind that the force was very lightly equipped, carrying no tents, and but a scanty supply of stores and ammunition. The loads of the boats of course varied with their size; a few of them are noted as follows:—thirty to one hundred armed soldiers; six to twelve horses; a gun with its limber complete and a few bullocks; two Commissariat store carts with bullocks, &c., &c., &c.

The black dotted lines on the Plan show the different routes of the boats. The majority were carried down to the island A, and were then tracked, by a circuitous course, up to the Lucknow Road Ghat (the only suitable spot for disembarkation); after discharging their loads, they were then tracked up as high as the magazine, from whence they were again ferried over to the Gora Ghat.

The government steamer *Berhampooter* was also brought into requisition for towing the boats; but as she could not cross the entire width of the river, owing to a shoal, she was not of very great use. She was, however, of assistance in somewhat relieving the labours of our boatmen, as she could tow five or six boats at a time, once and sometimes twice during the day, across to the island A, where she was obliged to cast them off, from thence she returned alone, not being able to make headway against the stream with even empty boats in tow.

I arrived at Cawnpore on the 25th July, and was present during the last three days of the passage. I calculated that the average distance traversed by each boat in both forward and return trips was six miles. No boat ever landed its cargo under four hours, or made more than two trips per diem: indeed some boats only made a single trip. On the 28th, the last day of the passage, the east wind sprang up, and the boats were able to sail directly across the river from Ghat to Ghat in three-quarters of an hour.

I may add, that this passage was not in any way opposed by the rebels, who never even made their appearance; and that the force was bivouacked in villages about two miles from the left bank of the river, where it remained until the whole of the baggage and stores had been passed over.

Second Passage—August 13th.

The difficulties and delays attendant upon the passage above described, early forced upon our attention the necessity of establishing, for subsequent operations, a more rapid mode of crossing the river.

Independently of the desideratum that we should be able to keep up a frequent and certain communication with General Neil, who commanded in the Cawnpore entrenchment, it was evident that if pressed by the rebels, we could not hope to effect our retreat by the circuitous passage, with or without the Lucknow Garrison, except at a most ruinous sacrifice of valuable lives; for our guns, on the Cawnpore bank of the river, could be of little or no assistance in preventing the enemy's establishing batteries at a distance, say, of even 500 yards from the left bank, from whence he would be able to interrupt, if not altogether to stop, our efforts to track the boats against the stream. No boatmen would have remained at work under fire; and our force was too small both to act on the defensive, and at the same time to furnish the necessary fatigue parties.

It will be observed, from the plan, that opposite to the entrenchment the river runs in four channels, the main one being on the Cawnpore side. Colonel Tytler now suggested what had occurred to him when fixing the site of the entrenchment, viz., the possibility of constructing a raised causeway from some point on the Lucknow Road, across the inundated main land near the river, over the three minor channels, and the three marshy islands, to the left bank of the main channel; whereby the passage in boats would be reduced to half the general width of the river, and to a single channel, in which the water being everywhere deep, the steamer would be of great service. Accordingly, on our first advance towards Lucknow, Lieut. Moorsom, of Her Majesty's 52nd Regiment, attached to the Quarter-Master General's Department, was directed to make the necessary surveys, and, if possible, to carry out the project, so that all might be ready for us on our return.

We advanced on the 29th July, and on that day engaged and routed two forces of the rebels at Oonao and Busherat Gunge, (distant respectively 10 and 15 miles from the river), and captured 19 guns. The General, however, determined before proceeding any further, to return towards Cawnpore for reinforcements, and, on the 31st July, took up a strong position at Mungalwara, a village about six miles from the river.

I was engaged for three days in constructing batteries, and in otherwise strengthening our position; but on the 3rd August, I proceeded to examine the line for the causeway that had been marked out by Lieutenant Moorsom, during our absence.

I found that the ground between the road and river was inundated to a depth varying from 6 inches to 2 feet; and that it was intersected by a deep and rapid stream *a*, *a*, *a*, about 30 feet in width; that bridges of boats would be required for the three minor channels; that the islands, though in some places dry, (more particularly near the banks) were for the most part flooded, and at many places to a depth of 3 feet; and that the soil of the islands would not admit of the passage of our guns and heavy store carts.

Lieutenant Moorsom had selected the best line, which proved to be about 1¼ miles in length.

The project of the causeway appeared, and indeed was pronounced by several officers to be quite chimerical; but the results dependent upon it were of such vital importance, that I could not but feel, from the very first, a conviction that we were bound to strain every effort to accomplish it, even although we might not be successful; for we had everything to gain by it, and failure could not place us in a worse position.

Accordingly, instructions were given to Lieut. Watson, of the Bengal Engineers, to commence work forthwith; to collect labourers from Cawnpore and the surrounding villages; to cut down and collect the long grass that grew on the islands; to send boats for brushwood that was to be obtained from a place 8 miles up the river; and to collect near the site of the causeway, at all places where the water was deep, a number of wooden platforms that were piled at the Lucknow Road Ghat, and that had been used during the cold season for forming a causeway across the dry sandy bed of the river. These platforms were 8 feet long by 6 feet wide, and were composed of 3-inch planks spiked to battens 4 inches square.

On the following day (4th August), I received orders to join General Havelock, as he had determined upon again advancing, having received intelligence that the rebels had re-occupied Busherat Gunge, in force, and as there was no immediate prospect of being reinforced. During the halt 60 European Infantry, 3 light guns, and two 24-pdr. guns had been added to the force.

On the 5th August we again met and defeated the rebels at Busherat Gunge, but did not capture any guns. And now for reasons that it is not necessary to detail here, it was decided that we must, for the present, abandon our hazardous enterprise of relieving the Lucknow Garrison; so for the second time our force returned to its former position at Mungalwara.

The importance of securing a rapid and secure passage across the river was now more than ever evident.

The Lucknow rebels had shown a determination to hover about and annoy us, and we had received information that Cawnpore was threatened by two forces that were collecting at Bithoor and Sheorajpore, distant respectively 12 and 21 miles from the entrenchment; the General therefore determined upon holding his position at Mungalwara, until I had completed the best possible arrangements for the passage of the river.

Further defensive operations for the security of this position detained me in camp until the 7th August, when I again visited the river. I found that Lieutenant Watson had collected a great number of platforms, and a good supply of grass and brushwood, and that he had raised a considerable portion of the causeway between the road and the river; but that a "*fresh*" had washed away much that had been done, and carried away a pile bridge, of a single 10 feet opening, that he had constructed over the stream *a*, *a*, *a*.

On the 8th, we set to work at the causeway across the islands, in good earnest, with about 1,000 native labourers and boatmen. We attacked the worst places first of all, and made such good progress that I felt convinced we should succeed. Two methods of raising the roadway were adopted—1st. Where the water was not very deep, a double row of platforms (placed lengthways) was laid on the surface of the ground, being weighted with clods of earth to prevent them from floating; on this a second, then a third, and sometimes a fourth or even fifth double row were piled, until a sufficient height, clear of flood level, had been gained. Grass was then packed on these platforms, to fill up broken places and crevices between the planks, and over all was spread a 6-inch coating of earth. The causeway thus completed was about 12 feet in width; 2nd. When the water was deep, an abundant supply of brushwood was first thrown in; this was carefully arranged in layers of bundles, and trodden down by men's feet into a tolerably compact mass, and then held in position by a few stakes driven through it into the ground. By this arrangement the flow of the water which was perceptible, was not altogether obstructed, and a considerable height of causeway (perhaps 2 feet) was gained in a very rapid manner. The causeway was then completed with the double rows of platforms, grass, and earth, as above described.

On the 9th, work was again resumed with the same success as on the preceding day; the causeway between the Lucknow Road and the river was completed, and a pile bridge, having two openings, each 15 feet in width, was completed across the stream *a, a, a.*

On the 10th, two boat-bridges, the one containing four and the other six boats, were thrown across the two minor channels nearest to the left bank; and the third bridge, for the broadest of these channels, was commenced.

On the 11th, a long pier-head was constructed on the island A at the place of embarkation; also two pier-heads for disembarkation on the Cawnpore side of the river; the third boat-bridge, containing twelve boats, and the whole of the causeway, were also completed; and everything was ready for the passage of the Force, when intelligence was received that the enemy had for the third time occupied Busherat Gunge in force, and taken up a strong position about a mile and a half in front of it. General Havelock at once determined to attack and drive them back, and during the afternoon, marched five miles to Oonao, where he bivouacked for the night.

On the 12th, we advanced and once more defeated the rebels at Busherat Gunge, capturing two of their guns, and putting them to complete rout; and as these repeated advances of the enemy warned us that the success of an uninterrupted retreat to Cawnpore depended upon the celerity of our movements, the force marched back to Mungalwara during the afternoon, whilst I returned direct to the river to prepare everything for the passage on the morrow.

I may here mention that, after it had been finally determined that we should retreat across the river, everything that could be spared in the shape of stores, ammunition, baggage, bedding, &c., &c., &c., had been gradually despatched to Cawnpore in boats, so that we might be in as light marching order as possible for the final move.

On the morning of the 13th, everything was ready. All the boats were collected at the pier-head at island A, as well as the steamer, with a flat in tow, constructed by Lieutenant Colonel Tytler, and composed of four large boats decked over from stem to stern, and capable of conveying a complete battery with its bullocks.

The passage commenced at 8 A.M. The column moved down to the place of embarkation in the usual order of march, and the several regiments and batteries, as they came in succession, were shipped on board the boats and flats, and were rapidly carried over by the steamer and the favouring wind to the Cawnpore side of the river. About sixty boats of all sizes, and 300 boatmen, were employed. Each boat on an average made two trips, and the steamer transported four cargoes. We suffered no interruption from the enemy; there was not the slightest confusion or accident; the troops were not harassed by fatigue duties; they were rapidly placed in quarters, and consequently suffered neither exposure nor fatigue. By half-past 1 o'clock (that is to say in $5\frac{1}{2}$ hours), the whole force had crossed, with exception of the rear guard, which remained on board the steamer, ready to protect the party that were engaged in breaking up the bridges; by 5 o'clock this operation was completed, and the boats placed in security with their superstructure packed on board.

The passage was thus successfully completed in less than a single day, and greatly relieved the mind of General Havelock, who had repeatedly expressed his anxiety regarding it, and had stated that he considered the retreat a most delicate and difficult undertaking.

During the whole of the operations, I received the most cordial assistance from Lieut. Colonel Tytler, who, with the aid of Lieutenant Moorsom, of Her Majesty's 52nd Regiment, and Lieutenant Simpson, of the 39th Native Infantry, superintended the disembarkation of the Force. The last mentioned officer had for some days been placed in charge of the boats and of the boatmen, and did good service in keeping them together and in order.

Captain Dixon, who commanded the steamer, performed his duties in the most satisfactory manner, and was complimented by the General for the skill and energy he had displayed in the management of his vessel.

I have also much pleasure in recording the aid I received from Captain Maycock, of Her Majesty's 75th Regiment, and attached to the Quarter-Master General's Department. This officer was employed upon the very fatiguing duty of sending across to Cawnpore all the spare stores, before the final move, and in assisting me to embark the Troops.

I am also very greatly indebted to Lieutenant Watson, of the Bengal Engineers, and Mr. Thomas, civil engineer, who assisted me with right good will in the construction of the causeway and bridges of boats. These duties were of the most arduous nature that I have ever experienced. We had no subordinates or non-commissioned officers to assist us, and we were therefore ourselves obliged to superintend the whole of the work. For four days we were hard at work in the water, labouring with our own hands, and exposed alternately to a drenching rain and a scorching sun.

I may add that on the 16th, we attacked and defeated the enemy at Bithoor, and that when we returned to Cawnpore on the 17th, we found the Lucknow rebels, who had been too much scared by their last defeat to follow us up immediately, in possession of the opposite bank of the river, close to which they remained until we forced the third passage that I shall now proceed to describe. It may therefore fairly be argued that had not our retreat been most rapidly effected, we should have been subjected to great annoyance and loss.

Third Passage—September 19th and 20th.

As it was quite certain that some considerable time would elapse before we could receive sufficient reinforcements to enable us to repeat our attempt at relieving the Lucknow Garrison, I determined upon preparing for the boats as much bridge-equipment as the available means and time would allow. I had not any fixed idea of constructing a bridge of boats across the main channel, because at first it appeared that for this purpose we could not possibly collect sufficient materials; and moreover, as the enemy were in possession of the opposite bank of the river, we could not decide until the time for movement approached, at what point it would be most advisable to force our passage. Still it was quite clear that our time could not be misspent in arranging for a bridge; and I was the more induced to make every possible preparation, because, although our last passage had proved most satisfactory, we could not hope for like success under an anticipated alteration of circumstances; for instance, we could not depend upon the long continuance of the favourable wind that had proved of such assistance to us; again, the river might fall and become so shallow in parts that we might not be able to use the steamer. Deprived of these two great aids, and seeing that in all likelihood our force and equipments would be doubled, it was evident that our passage in boats must necessarily be a long one.

We found two or three timber yards on which we could draw for baulks and planks; and we also found eighteen boats partly equipped with the materials of the bridge that is annually constructed during the dry season at the Gora Ghat. The variable dimensions of the available timber (especially as regards length) would not admit of my fixing upon any uniform plan of construction: some of the timbers were sufficiently long to answer as baulks for spanning both a boat and its adjoining bay; others were only long enough for spanning either a boat or a bay; whilst for the boats already described as partly equipped, it appeared advisable to carry out the plan therein adopted for carrying the superstructure, especially as it economised long timbers, viz., to form the baulks of short lengths, and to support them with uprights and diagonals from the bottom of the boat. I however determined that the following general rules should be adhered to, that the width of the bridge should be twelve feet; that as a general rule five baulks should be used; that the bays should be 15 feet wide.

The boats suitable for the bridge were of various sizes; all flat bottomed with sloping sides, pointed at both ends, and rising slightly to the stem and stern from a point distant from each about one third of a boat's length. Eighteen of the boats were very cumbrous and unmanageable, and had been built expressly for the cold weather bridges, the remainder were the common craft employed in the navigation of the river; their length ranged from 30 to 50 feet, and their breadth between gunwales from 12 to 15 feet.

I have already mentioned that on the 18th August the rebels occupied the opposite bank of the river. We could see four of their camps distant from one to four miles from the river. They daily crowded to the Lucknow Road Ghat for the purpose of bathing, and employed themselves very busily in destroying our causeway and in opening trenches; a few of them occasionally made their appearance at the pier-head on island A, their approach being concealed by the long grass We did not open our guns upon them as we had no ammunition to spare, and because we were unwilling to draw their fire upon the town and entrenchment.

During our halt I made several reconnoissances with Lieutenant Colonel Tytler both up and down the river. Everywhere we traced signs of the enemy on the opposite bank; and ascertained the existence of shoals to be so universal, that it would not be possible to make a direct passage across the river even in boats, or to use the steamer at any point except in the immediate neighbourhood of the entrenchment. We also found that the country on the opposite bank was inundated, more or less, for a considerable distance inland, and intersected by numerous streams, thus rendering the movements of troops, except along the Trunk Road, most difficult, perhaps impossible.

Under ordinary circumstances, it would have been advisable to have forced the passage, by simultaneous movements at two or more points; but the state of affairs above noted clearly indicated that such combined operations would be most uncertain and hazardous. Nor did it appear advisable to divide our limited resources, or harass our men, by making a feint at any particular spot distant from the intended place of crossing, because, independently of our being closely watched, and of all our movements being reported by spies in the camp and town, a surprise was hopeless, considering that cross where we would, the operation must necessarily be a lengthened one.

For these and other reasons, it was decided that we should concentrate our efforts upon a single passage, and the former route by the islands was selected for the attempt, because here at least we knew the condition of the river—were close to the town and bazaars—and could derive support from our guns in the entrenchment.

On the morning of the 14th September we discovered that the rebels had, during the preceding night, commenced a battery close to the site of our former first bridge of boats; and as our reinforcements were close at hand, we opened upon it and the bathers at the Lucknow Road Ghat, our two 24-pdr. guns that had been posted in a high plateau close to the river bank, about 400 yards to the left of the entrenchment. The shot ranged well inland, and the enemy were soon driven off. During the afternoon we arranged to cross over to the opposite bank in the steamer with 100 men to ascertain what the enemy had been doing, the condition of the causeway, and the depth of water in the three minor channels. A shoal had formed about midway across the main channel, where a month before the water was 22 feet deep; consequently the steamer grounded and could not be got off until the following morning. The enemy turned out in full force, but did not approach within range of our 24-pdr. guns.

On the morning of the 15th we repeated our attempt in boats with perfect success. We found that the trenches made by the enemy were unimportant, that owing to the fall of the river (about three feet), the three minor channels were fordable; that the causeway across the second island nearest Cawnpore was almost uninjured, but that across the third island it was completely destroyed. This was not, however, of any consequence, as the island was no longer flooded; and lastly, that after the force was landed on island A, there was no obstacle, but the enemy, to its passing onward to the mainland.

The three minor channels having become fordable, the 22 boats before used in bridging them were available for the bridge across the main channel, the attempt to construct which was not determined upon.

The bridge was commenced on the morning of the 16th, but the greater portion of the day was occupied in dropping down below its site the majority of the boats that had been collected at the Gora Ghat for another purpose. Consequently only six boats were in position by the evening.

On the morning of the 17th, 300 men of Brasyer's Seikh Regiment were sent over to the island A, to check the rebels from approaching too near to annoy us in our operations. The enemy at an early hour sent skirmishers into the long grass of the other islands; but though they fired the whole day, they did no harm; in the afternoon their whole force turned out; but, as on a previous occasion, did not venture within range of our heavy guns.

During the day 35 boats were placed in position; work was continued during the night, and by the morning of the 18th the bridge was completed to the shoal (shown in the Plan) that had made its appearance the preceding day above the surface of the water; a causeway across this shoal, about 150 feet in length, was also completed.

On the morning of the 18th, it was thought advisable to reinforce the Seikhs with 100 men of the 78th Highlanders and 4 guns of Maude's battery, and to make a small breastwork for their protection. The skirmishers of the rebels again commenced their work of annoyance at an early hour, and a considerable body of their Infantry were approaching the river, when Maude's guns opened upon them, and forced them to beat a rapid retreat. They then brought down 3 guns, which they fired from long ranges; and throughout the whole day there was a constant cannonade from both parties. Little or no harm was done, although several shots dropped amongst the workmen. By the afternoon the remaining portion of the bridge, composed of 22 boats, was nearly completed, when a gale of wind, from the east, accompanied by heavy rain, stopped our work for about two hours. The gale, although blowing against the rapid stream, nearly carried away the short portion of the bridge which had been commenced at both ends, but which was not quite united in the centre, and forced into a very tortuous shape about 400 feet of the large bridge (near the shoal) that was in comparatively slack water. Before night, however, all damage had been repaired and everything made ready for the passage of the Troops on the following morning.

On the morning of the 19th, the whole Force, consisting of about 3,500 men of all arms, with 12 field guns, crossed the bridge and islands before sunrise, and took up a position along a ridge of sand hills about three-quarters of a mile from the left main bank of the river; and by noon the camp was pitched. The enemy offered but slight resistance; for in fact our force crossed, and was drawn up in position so rapidly, and at such an early hour, that they were taken by surprise, and had not time to unite their detachments from the several camps for the purpose of making an effective stand. The three minor channels, with their muddy banks and bottoms, proved serious obstacles to the rapid passage of our heavy carts and waggons; but by the afternoon of the 20th the whole of the ammunition, stores, and baggage had passed over, and the advance towards Lucknow was commenced on the following morning.

Thus this bridge, 2,090 feet in length, and composed of 74 boats, with irregular superstructure, was constructed entirely by undisciplined boatmen and labourers, under the superintendence of the Engineer Department, across the Ganges, in its floods running in many places more than six miles an hour, in about 42 working hours.

There was nothing very novel or scientific in the details of the bridge; indeed, though amply strong and well secured, it was of a rude description. Still a short account of a few of these details, and of some of our arrangements for expediting its construction, will, I think, prove interesting, and perhaps useful.

I have already noticed that the whole of the boats were collected below the site of the bridge; this was done for the following reason: I had satisfied myself, after a good deal of experience, that in rapid streams, where large heavy boats are used, attempts to drop the boats into position from "above bridge" are invariably attended with delay, frequently with accidents to the boats themselves, or to the standing part of the bridge, and sometimes with total failure. I therefore determined to haul the boats into position from the shore along the stern of the bridge, and then into the proper alignment by cables attached to anchors that were to be previously laid.

The anchors, which were of two sizes, were thus formed: two stout pieces of timber, varying from four to eight feet in length, according to the size of anchor, of any section, but of curved shape when we could so get them, were halved into each other crossways, and secured together by iron spikes; into these, about a foot from their ends, which were pointed, four upright bamboos were fixed, meeting in a point at a height of four or eight feet; stout coarse matting was then firmly lashed round the bamboos, thus forming a receptacle for a good heavy supply of road metal that we found collected for the repairs of the station roads. In the shallow or slack portion of the stream, several of the small anchors were taken out in a row boat, and dropped into their proper places, one for each boat. Where the water was deep and rapid, the large anchors were used; three of them, having three cables attached to each, were placed on a large boat, which was then towed out into the stream by the steamer, they were then, one by one, dropped into the current into their proper places, and their cables were taken down to the standing part of the bridge by the boat still holding on to the steamer, which towed it again to the shore. By this latter arrangement much time and labour was saved; for in the first place, moorings for nine boats were laid by a single operation, since each anchor was heavy enough to support three boats; and in the second place, we were able to haul upon these anchors at once, as their weight was sufficient to keep them from rolling; whereas, had we used the small anchors we should have been obliged to let them remain at the bottom of the river for at least an hour before we could have brought them into use, in order to let the sand silt around them, and thus prevent their moving. The cables were made of moonj grass, which does not decay rapidly in water, and were from 3 to 6 inches in diameter.

PART OF THE CAWNPOOR CANTONMENT.
Masonic Lodge
Theatre
Assembly Rooms
Hotel
Sursyea Ghat
Well
Redoubt
Madras Fusiliers
Work Shop
Buxee Ghat
INTRENCHMENT
Well
Well
Hospital
Well
Laboratory
CANAL
Stockade
Bridge of Boats constructed on 16th 17th and 18th Septr. 1857
52 Boats
22 Boats
RIVER
A

The baulks, as I have before mentioned, were of various lengths and scantlings; they were used just in the rough state that we found them in at the timber yards, and they were laid in five longitudinal rows: where stout enough they were used singly, but when weak they were doubled; they were kept at the proper distance apart by cleats spiked to the gunwales of the boats, and as, from the twisted shape of the timbers, it would have been impossible to have bolted the several sets together longitudinally, they were made to overlap well, and then firmly bound together to the transverse beams of the boats by numerous racklashings.

This laying of the baulks was the most tedious and difficult part of the construction. No two sets can be said to have been treated exactly alike; sometimes we were lucky enough to get a complete set that required nothing but cleating and lashing; but generally they had to be packed and wedged up in various ways, so as to secure level bearings for the planks of the superstructure.

The superstructure was composed of rough planks, joists, and small poles laid across the baulks; on these a plentiful supply of grass was packed to fill up all crevices and inequalities, and to form a tolerably level surface for the reception of a thick coating of earth.

The whole of the Engineer officers present with the force, viz., Captain Impey, Lieutenants Watson, Russell, Limond and Judge, and Conductor H. Dewes (a volunteer) were untiring in their efforts to ensure the speedy construction of the bridge, and I am much indebted to them for their hearty co-operation. But my thanks are especially due to Captain Impey, who, arriving at Cawnpore with the reinforcements on the morning that we commenced the bridge, waived his seniority of rank, and rendered me the most valuable aid by working under my orders.

Much credit is also due to Lieutenant Watson for the satisfactory manner in which he performed the duty that had been entrusted to him of collecting materials and preparing the boats.

W. A. CROMMELIN, Captain,

Late Chief Engineer, Oude Field Force.

February, 1858.

PAPER XIX.

REMARKS ON MILITARY AND CONVICT LABOUR, AS EMPLOYED IN WESTERN AUSTRALIA, FROM 1851 TO 1858.

BY CAPTAIN WRAY, ROYAL ENGINEERS.

As the Convict system in Western Australia was in many respects different from that in the other Australian colonies, and almost entirely different from the systems at Bermuda and Gibraltar, it may be useful to give a slight sketch of it here in order to make the following remarks on piece and task work intelligible.

The Colony of Western Australia was founded in 1829, and was made a penal settlement in 1850. For this it is eminently suited. The climate is, though very hot from December till April, exceedingly healthy; there is no possibility of escape by land, and very little probability of escape by sea; while the population is so scattered that a convict at large, attempting to live by bush ranging, would be tracked and captured in a very short time.

When it was decided to send Convicts to the colony, Captain Henderson, R.E., was appointed Comptroller General. He went out early in 1850 in the first ship, with 75 picked convicts and the necessary officers. A Clerk of Works and five non-commissioned officers of the Royal Engineers also accompanied him.

These latter were employed entirely in a civil capacity under the Superintendent of the Prison and Clerk of Works, and were called "Instructing Warders." Their duties consisted in attending the Convict parades, and marching their parties to and from the works, being responsible for the safe custody and behaviour of the Convicts, and for the proper execution of the work. They received 2s. a day, Sundays included, on which day they took, in turn, their share of the disciplinary duties of the prison.

The disciplinary duties, when the rest of the Company of Sappers arrived, and more Instructing Warders were appointed, were found inconvenient, and were done away with except at one or two out-stations, a Civil Warder being attached to each party, leaving the non-commissioned officer or Sapper at liberty to give his entire attention to the superintendence of the work.

The 20th Company, with Lieutenants Wray, Du Cane, and Crossman, R.E., left England in September and October, 1851, arriving in Western Australia in December and January, 1852, and were located as follows:—

Lieutenant Wray, with about 70 men, remained at Fremantle, the head-quarters of the convict service, where the prison and other buildings were to be erected. One or two out-stations, Bunbury, and Mount Eliza, and sometimes Perth, and also a few roads were attached to this station.

Lieutenant Du Cane, with a party of 4 men, was detached to Guilford, having charge of the works there, and at York and Toodyay, where there were also detachments of 4 men each, and of the roads and bridges in the Eastern district.

Lieutenant Crossman was detached with a party of 6 men to Albany, having a charge similar to that of Lieutenant Du Cane.

The Convicts are divided in the colony into three distinct classes—1st. The Probation Convict, who is undergoing the portion of his sentence on the public works; 2nd. The Ticket-of-leave man, who has undergone the first portion, and is at liberty to work for hire under slight restrictions; 3rd. The Reconvicted Convict, who has been on ticket-of-leave, misconducted himself seriously, and been sent back to prison by the magistrate; and lastly, though this class cannot be regarded as Convicts, the Conditional pardon man, who has received, after a certain term of good conduct, a pardon on condition that he does not return to England or the British colony where he may have been originally convicted, until after the expiration of his original sentence. This renders the holder a free man everywhere but in the places named in the pardon.

The Convicts sent out to the colony were supposed to be able bodied men, whose crimes were not of the worst description, and who had shown, whilst undergoing solitary confinement in England, some sign to lead to the hope that they were so far reformed that on being started in a new country, where labour was scarce, they would prefer an honest life to a dishonest one.

On arrival they were (with the exception of two or three shiploads who were entitled, by servitude in the home prisons, to ticket-of-leave on landing) located in the Fremantle Prison, and employed on the public works at that place.

As the period of their probation drew to a close, they were generally sent to detached stations, or road parties, where the superintendence and means of correction could not be so systematic as at the Head-quarter Prison.

During this probationary period a small daily sum, about 1½d., was allowed them, the whole of which was placed to their credit to accumulate for them until the time of their going on ticket-of-leave. Their conduct continuing satisfactory, they received, when their probation period, which was always in proportion to the length of their original sentences, had fully expired, a ticket-of-leave, which permitted them to move about within a given district, liable to certain restrictions.

The colony had already been divided into districts for the purposes of government, and a Resident Magistrate appointed over each. When a Convict received a ticket-of-leave, he was provided with a written pass to the district to which he was told off, his departure for that district being notified by post to the Resident Magistrate who entered him on the district register. He reported his own arrival, and was not permitted to go beyond the limits of his district without a pass from the Resident Magistrate. He was at liberty to earn any wages he could get, in any capacity but that of publican, and the sole restrictions he was liable to were that he must not be out after 10 P.M., must not carry fire-arms, and must account for his mode of getting a livelihood to any magistrate who asked him to do so. If he wanted to change his district he could do so on application to the Comptroller General.

At first every man who went out on ticket-of-leave got employment; but after a time it became necessary to provide places in the districts, where unemployed Ticket-of-leave men could go, and buildings at the out-stations were erected for these hiring depôts. They were opened in 1851, and the men were paid by piece-work, which enabled them to earn about 1s. 4d. a day, besides which they were well fed and lodged. They did not receive in cash more than 2s. a week of their earnings, the rest being credited to them and expended in clothing, as they required it, the balance being paid to them on their entering private service.

It was found that at this rate the Ticket-of-leave man in depôt was better off than his fellows in private service, and the settlers justly complained that the price of labour was not lowered by the importation of Convicts.

Now it is quite clear that at such work as road-clearing, collecting and breaking stones, felling trees, &c., with such hands as untrained farm labourers, or town pick-pockets, it is impossible to fix any scale of piece-work which would enable all and each to earn just 1s. 4d. or 1s. 6d., and no more.

The strong man, used to work, would earn 2s. or 2s. 6d., while the weak man would not earn 1s.; and as it was necessary to fix such a scale as would allow the weak, though willing, man to earn his day's pay, the strong man could, with ease to himself, earn more than any settler could afford to give.

The rate proved too high, but the principle was a bad one, and though the scale was reduced, first to such figures that the weak man might earn 9¼d., then to 8½d., and afterwards to 6½d., it was found impracticable to work it satisfactorily, and day-work was substituted. Finally, in 1857, pay to Ticket-of-leave men on the public works was abolished altogether, the men being fed and clothed at the public expense, and worked in gangs under the eye of a Warder, the sole difference between their treatment and that of the Probation Convicts being that they were at liberty to leave the depôts whenever they could find employment.

The result of this measure was that numbers of lazy men who had stayed in the depôts, preferring the light work and small pay to larger pay more justly earned, found those places no longer a lounge, and sought and found private employment.

The superintendence of the work of these Ticket-of-leave men was in almost every instance entrusted to the non-commissioned officers and men of the Royal Engineers, who set out and measured the work, and sent in to the Depôt-Clerks the necessary information for making out the pay-lists, which were checked and signed by the Engineer Officer in charge, on whose signature the money was issued by the Commissariat to the Convict Officer in charge of the depôt, who paid it in detail to the Ticket-of-leave men.

The only instances in which this work was not done by the non-commissioned officers or men of the Royal Engineers, were on two or three small and distant road clearing parties, where the work was not of sufficient magnitude to require both a discipline and instructing Warder. After the abolition of pay the non-commissioned officer or Sapper merely measured the work for the Returns, and as a check upon the amount of work done.

The conclusions arrived at by the writer of this Paper, as to the employment of Convicts or Ticket-of-leave men in such a place as Western Australia, were decidedly adverse to either piece-work or task-work.

Piece-work would be the best way of employing them, if there were an opportunity of keeping them constantly on some work of uniform character, such as quarrying stone, but even in this case, where the pay (for Ticket-of-leave men only) is obliged to be enough for the weak, and not too much for the strong, the difficulty can only be overcome by the classification of men according to strength, which is, if anything, more difficult to arrange than the scale of prices.

In fact piece-work for pay can only be carried out satisfactorily where the men are allowed to earn as much as they can in a given time, and it is therefore inapplicable to Ticket-of-leave men.

Piece-work for remission of time is applicable on such work as quarrying, and it was worked satisfactorily in the quarries at Fremantle with the Reconvicted Convicts before mentioned. It was afterwards discontinued, because the Governor held, and justly so, that a Convict whose ticket-of-leave had been revoked for serious misconduct, had no claim, on any grounds but continued good conduct, to be let loose again until the expiration of his original sentence, and he could not therefore be permitted to earn remission.

This plan of piece-work might be made to operate with Probation Convicts (who receive a small daily gratuity which it is not advisable to reduce, as it is given to provide a man, on discharge, with a small sum of money) but then equal remissions must in justice be allowed to the well-conducted Convicts employed as smiths, carpenters, masons, painters, shoemakers, tailors, cooks, bakers, &c., &c., whose work is not of a nature to be measured.

Task-work is totally inapplicable to Convicts, because a regulated number of hours must be spent on the public works, and it would be impolitic to give the men too much, or in fact any spare time.

The question of Convict employment is beset with difficulties, and by no system known to the writer, applicable on a large scale, will more than half the work, which would be done by hired labour, be obtained from Convicts. When a Superintending Officer is satisfied that he gets this, he ought to consider himself very lucky.

All forced (including military) labour, unless employed by piece or task work, is less profitable than it should be. It is human nature that where men are not paid according to ability, as in piece-work, or allowed to leave off when a given quantity of work is completed, as at task-work, the greatest amount of work of which they are capable will not be obtained, and what Convicts call "government stroke" will more or less prevail, however good the superintendence may be.

The 20th Company, Royal Engineers, were employed, wherever the nature of the work admitted of it, at piece-work, and without doubt with the best results, both as to the amount of work obtained and its economy.

The effect was great also in improving the men at their trades, whilst the punishment of reduction to a lower class was greater than it is under the ordinary day-work system; and at the same time the amount of work obtained was not lessened, as it very generally is, by reducing a man's pay at day-work.

The object of introducing piece-work was twofold—1st. That the men might earn enough to subsist their families, the prices of the necessaries of life being at first so high that the men could not possibly do so at the ordinary pay; 2nd. That each man might have a direct interest in making his Convict labourers work, and thereby save some superintendence of both.

The amount of work of various kinds requiring constant attention prevented an abstract of the wages earned by the Royal Engineers during 5 years being made, but the principles of framing the schedules with a close approach to the average wages earned will perhaps be found useful. There was some slight difficulty in introducing piece-work, owing to Article 12, Section xviii. of the Royal Engineer Code, providing that piece-work by military should be paid for at one half the rate paid to civilians for similar work. In Western Australia this would have amounted to 4s. a day, or more, and such a price would not have been either economical or for the good of discipline, but there was no power to enforce any other scale. However, the men were, generally speaking, only too glad to work on a scale which would permit them to earn at least 1s. 6d. a day, and those few who preferred day-work received the ordinary pay, care being taken to ascertain, by occasional measurement, that they did a fair day's work.

Schedules of piece-work prices were framed in the following manner; the London price-books being taken as a guide, and an old schedule made use of as a check.

It was intended that a good mechanic by very hard work might earn as much as 2s. a day; and as it was considered that more advantages were given for the performance of work in London than could be given in Western Australia, it was thought improbable that by a schedule framed on the London price-books the desired amount would often be exceeded.

For work where no labourer would be required, such as joiner's work, the price for labour only and the day's wages for a mechanic were taken out. A rule-of-three sum then gave the price for the Sapper's schedule.

Thus in 6-panel 2-inch deal doors, moulded both sides, the calculation stands—

	£	s.	d.
Price in London per foot superficial	0	0	$7\frac{1}{2}$
Day's wages for a joiner	0	6	0
Intended day's wages of Sapper	0	2	0

Then, if a man working at $7\frac{1}{2}$d. per foot can earn 6s., what price must the Sapper have, to earn 2s.?

Where there was a fraction in the result, the price per foot was set down at the next eighth of a penny above the fraction.

When labor in carpenter's or joiner's work would be allowed, a proportionate allowance of Convict labour was made.

For those trades in which no similar prices (in consequence of different materials being in use) could be got from the price-books, for instance, sawyers' and masons', a price was fixed from information obtained and observations made on the spot, and in no case but one, that of the sawyers, who were over-paid at first, was any reduction or alteration made in the prices.

It is of the utmost importance that as little alteration as possible should be made in piece-work prices, for if reductions are made the men will not work their best, because they argue "if we work hard and earn more than our officers want us to earn, we shall be cut down;" and if on the other hand increases are made, some of the men will hold back in their work in the hopes of getting such increase.

The schedules framed as above stated were brought into force in 1852, and were constantly worked until the time at which the writer of this Paper left the colony, viz., in February, 1858.

The earnings at first seldom exceeded 1s. 6d. a day, but by degrees the men improved so much at their trades that the pay of the masons, plasterers, and sawyers, in a year or two came up to the intended average of 2s, the pay of the carpenters and joiners being a little less, which was fair enough, as the wear and tear of clothes is less in the latter trades than in the former.

The smiths were mostly employed at work which it was not advisable to give to Convict smiths to do, such as lock and key making, (though even this work was sometimes given to Convicts) and as one was sent to each out-station to repair tools, it was seldom that more than one of the fires was worked by a Sapper; and his time was fully employed shoeing horses and repairing harness.

The schedule of this trade was therefore seldom used, and I imagine would always be difficult to work.

The smiths, plumbers, wheelwrights, and tradesmen, whose work was of too fine a nature for measurement, (modelling for casting, making cranes and tooth wheels, fitting pump gear, or winch work, for instance) were paid the average rate of the week if reported favourably upon by the non-commissioned officers and their work was approved by the Clerk of the Works.

This average at first was about 1s. 6d., which was the amount paid, except where one of a gang (say of masons) was taken off for day-work, when he got the average of the others.

The painters' and glaziers' work was usually done by convicts, the Sapper painters being chiefly employed as clerks.

CARPENTERS' SCHEDULE.—The stuff for joiners' work was cut out by a circular saw driven by a large wheel worked by six convicts, and the Sappers could get all superfluous stuff taken off by it.

In the carpenters' schedule it was found that the price for small sashes was too low; and panel-doors moulded, unless the same man, or pair of men, got a dozen or more of the same size to make, should have been paid for at a little higher figure. On the other hand rough roofing and battening were a trifle too high. The work done with the wood of the country called jarra or mahogany, was measured as deal, and $\frac{1}{3}$rd added. Shingling with shea oak (shingles 17″×4″ and laid to $5\frac{1}{2}$-inch gauge) was paid for at 2s. per square, the shingles being delivered on the roof.

MASONS' SCHEDULE.—The prices in this case were fixed from data obtained on the spot, the stone being a sandy limestone easily worked.

7d. a yard superficial was paid for rough walling 18 inches thick and under, properly bonded and flushed, faced both sides. For walls of greater thickness a small increase per yard superficial was made, to cover the extra filling in. No deductions were made for openings, or additions for coigns, but 1d. per foot run was allowed for reveals to doors and windows.

For rough ashlar, with beds horizontal and joints vertical, 9d. a yard superficial was allowed, with the same additions.

For the outside and corridor walls of the prison, which were from 2 feet 8 inches to 1 foot 8 inches thick, and of a superior description of ashlar, 1s. 5d. per yard superficial, with additions as above, was paid, and it was rather too little.

In the masons' work a labourer for each Sapper was allowed on the ground, the mortar and stone being delivered at the foot of the work. For every 4 feet in height an extra labourer was allowed for each pair of masons. These labourers had to carry up the stone and mortar, and erect scaffolding, and the Sappers were at liberty to employ them in rough dressing stone, if they could spare them at any time.

PLASTERERS' SCHEDULE.—The plasterers' schedule was the most profitable of any; but as it was framed like the carpenters', and there was no great amount of plasterers' work to be done, it was considered best not to reduce it, the more so as it was only after three or four years' experience that it was found to be too high. Labourers—one per man—besides mortar mixers, and the stuff delivered on the scaffold.

BRICKLAYERS' SCHEDULE.—The bricklayers' price of 11s. a rod was too low. The bricks were not good and of unequal size, and, besides, they had, at some of the stations, to be laid in mud instead of mortar.

At Fremantle the brick-work was generally in back arches over doors and windows or reveals, and it was measured as stone.

SAWYERS' SCHEDULE.—The sawyers received 2s. 4d. per 100 feet superficial for mahogany or the other gums, and 1s. 6d. per 100 feet superficial for deal.

In the mahogany, which was about equal to oak in hardness, but difficult to cut, in consequence of the great quantity of gum in it, the opening cut was measured, and then two sides of all beams and scantling; in deals, the number of cuts by the length and depth gave the number of feet superficial.

At these prices they earned about 13s. a week, and had to assist in getting up all the logs, which came by water (only a few came by land carriage), from high-water mark. This was done by means of a whim and crab winch, and as there were 19 pits going, and each pit required on an average two logs a week, the greater part of two days were thus consumed weekly, the distance from ordinary high water-mark to the first pit being about 40 yards.

The advantages of employing the Royal Engineers, on any military labour, at piece-work, are many, and besides the two most palpable, viz., that the government pays for no more work than is actually done, and that the work is done quicker and willingly, it gives a means of punishment incomparably superior to the ordinary reduction of working pay.

If the reduction of ¼th for each class be made, the principle remains the same, but though the loss is greater the defaulter must nevertheless do his full day's work for his three-fourths or half day's pay, and his comrades, if the men are working in a gang (of masons or plasterers, for instance) or in pairs, will, for their own sakes, see that he does not shirk.

Again it is tolerably certain that when a Sapper is reduced for misconduct to the lowest class of daily working-pay, *i.e.*, 6d., the work he does is not more than one-half of what he would do at 1s., for the sum earned is so small that very few men will exert themselves for it, and in this case the defaulter would be better at fatigue or drill than setting a bad example on the works. At piece-work, for the reasons above stated, the amount of work done must be the same, and the sum earned is still worth working for.

Another advantage is that it compels an attention to detail on the part of the Superintending Officer, in order to prevent scamping and to enable him to settle questions as to quality or quantity of work performed.

This "scamping" work is the principal, if not only, objection to it in ordinary cases; but it is only necessary to visit the works at uncertain times, and let the men see clearly that bad work will not be permitted, and attempts at "scamping" will soon cease.

The only serious objection to it in Western Australia was that it was a direct inducement to the Sappers to fee their Convict labourers with tobacco or grog, and was productive of familiarity between them. This familiarity will exist to some extent without piece-work, and it must be stated that during six years there was only one charge of supplying grog or tobacco to a Convict, brought home to a Sapper, who was a joiner by trade, and whose object in supplying it (the Convict being a cobbler and in no way connected with him), was never clearly ascertained.

The advantages of piece-work may be summed up as follows:—The work is done better and more cheaply; superintendence in detail is saved; the men improve faster at their trades; the punishment of reduction is heavier and more certain in its application; and the pecuniary condition of the well conducted and skilful Sapper is improved, by which a superior stamp of recruit may be obtained and desertion rendered less frequent.

The sole disadvantage in ordinary circumstances is the inducement to "scamp" work, which, on the other hand, compels a closer attention to detail on the part of the Superintending Officer; and, where Convicts are the labourers, the increase of familiarity above alluded to.

Some prices for road-clearing might be given, but only the Ticket-of-leave men were employed at this work, and they took very good care, if the prices were sufficient to enable them to earn about what they were intended to earn, not to earn more, so that they are of no practical value in themselves. If they were to be depended upon as results, the different description of timber to be cleared would render them of little value in other places.

The simplest way of ascertaining what a gang of men should do, would be to employ a certain number of free men to do a certain amount of similar work by contract, binding them to work a given number of hours a day.

In fixing piece-work prices in this way, it should always be borne in mind that it is difficult to cut down a price, and it is therefore not advisable to put the rate too high in the first instance.

PAPER XX.

ON THE PROBABLE INFLUENCE OF THE MODERN RIFLE IN THE FIELD, AND THE NECESSITY FOR AN INCREASED USE OF ENTRENCHMENTS IN FUTURE FIELD OPERATIONS.

BY CAPTAIN TYLER, R.E.

Although there has been but little written by the Corps on the subject, there must yet be few Engineer Officers who have not reflected much upon the alterations in military tactics which the improved weapons supplied to the Infantry of late years are likely to produce.

Changes have been brought about during the last 10 years to which the history of the world can furnish no parallel. Expanding elongated shot and rifled barrels have been so effectively combined that our Infantry are supplied with weapons, which, being easily loaded, will range accurately for 600, and effectively for 1,000 yards; and the means exist of furnishing them with weapons which will range to a much greater distance. The Whitworth Rifle, for instance, will range effectively up to 1,500 yards, a distance at which Infantry cannot be distinguished from Cavalry by the naked eye. By the application of improved principles to Artillery, the range and accuracy of great guns, also, are being increased to an extent which we are unable as yet fully to realize, but which will obviously, under ordinary circumstances, exceed the limits up to which the inequalities of the surface of the ground will admit of their being employed in the field. As might be expected, a considerable amount of discussion has been carried on of late as to the alterations that are likely to result from these vast improvements in the tactical relations of the three arms of Cavalry, Artillery, and Infantry, to each other; and I will commence by offering a few remarks upon this question.

In the first place, those ranges which have been hitherto exclusively at the command of the Artillery, may now, to a great extent, be advantageously adopted, up to 1,000 yards, by the Infantry,* while the power of the former appears likely again to surpass the latter, and partially, if not wholly, to re-establish its former preponderance.

Common case and canister, up to 300 or 400 yards, will continue to be applicable for assisting in the defence of the ditches of fortified works, or of defiles, against masses of troops that are approaching guns under cover, and in cases of a similar nature, as well as against Cavalry. Shot and shells will still be employed against masses of troops, though these will also, to a certain extent, be supplanted by Infantry fire, up to the distances for which the latter may be available.

The next question that arises is as to the capability of Artillery to withstand the newly acquired powers of the Infantry. It is clear that common case and canister would be unavailing against Infantry firing at the gunners at ranges of 600 or 800 yards. Spherical case, shot, and shell, though very destructive against troops in close

* See Article on "Recent Improvements in Fire-arms," by Major Ewart, R.E., at page 47, Vol. 7, of this Series.—ED.

order, could not seriously impede the progress of skirmishers in extended order, concealing themselves skilfully, as far as opportunity offered, commencing their fire at 1,000 yards, and advancing gradually forward until every gun had been silenced. It would be a waste of Artillery amunition to fire against such men, if they were well trained and properly handled; and it would be folly to expose uncovered gunners to such unequal odds. Skirmishers acting on the flanks of the Artillery would of course be even more effective than those in front; neither in the one case nor in the other could their fire be more than partially kept under by skirmishers acting with the Artillery, though these would be able themselves to act, in like manner, upon the enemy's Artillery, and upon the masses of their opponents, whenever they were within their reach.

In making these comparisons, it is by no means right to suppose that Infantry will make the same accurate practice in the field as at a target. It cannot be expected that they will do so, and as those who looked for great things from Enfield or Minié Rifles in the hands of untrained men in the Crimea were disappointed, so also it is probable that those who anticipate from well trained men the best results at the opening of a future campaign, will not find their expectations answered. But it may at the same time be fairly assumed that our Infantry, carrying into the field the vastly superior weapon with which they are now provided, and prepared by a careful course of instruction for the use of that weapon, will exhibit in the first instance a considerable proportion of that good practice which we have seen recorded as being performed by them from time to time; and that, as they gain experience in actual warfare, and learn their real power, they will acquire a degree of perfection which will fully justify the conclusions which I have drawn as to their relation in future to Artillery. For the past, it is more surprising to see by Prince Menschikoff's despatch after the battle of the Alma, that all his gunners were there "successivement tués," than to learn the want of success of the Enfield Rifles, in the hands of uninstructed men, against the Russian Cavalry at Balaklava. In looking forward to the future, we may, without being at all over sanguine, feel confident that results will be produced, such as will astonish, both those who endeavoured to oppose the introduction of the rifle altogether, and those who would now persuade us that it will make little or no difference in future combats.

The new rifles will undoubtedly tend, therefore, to render Infantry more independent of Artillery, by giving them the means of destroying their uncovered enemies at such ranges as will ordinarily be afforded by the nature of the ground, as well as to make the Infantry more than a match for Artillery in the field, instead of their being liable to suffer so much from its fire as they did formerly at a range of half a mile. But it must not be forgotten, on the other hand, that Infantry will now be liable to destruction by Artillery, when exposed in masses to its fire, at much greater ranges; or that it will more than ever require the aid of Artillery, and of improved Artillery, in the attack of defensible posts or positions, and in siege operations.

The employment of the rifle so favours the defence that it is difficult to see how, when even a comparatively small number of riflemen are placed behind judiciously constructed works, or skilfully employed obstacles, any body of unsupported Infantry can advance during daylight to attack them, without such loss as will render success impossible. A well directed distant Artillery fire, to ruin the defences, or a well sustained fire of shells at high angles, to clear the parapets, or both, must be employed in order to enable an assault to be advantageously made against men so posted. It is fortunate for the attack that the principles which have done so much for the rifle have now been applied to large guns; and that material assistance will thus be rendered in destroying the preponderance which the efficiency of the smaller weapon had afforded to the defence even of insignificant works and obstacles.

It would appear, upon the whole, that the duties of Artillery will be materially modified; that they will now have to act more from under cover, or at longer ranges; that their services will be called for more against materials, and less against men; and that they will have to use shot and shell more (and those, we may now fairly hope, of improved descriptions), and grape, case-shot, and spherical case, less.

With regard to Cavalry, it will not be necessary to say so much. "The objects of the institution of Cavalry," as Marmont says, "are close combats and hand to hand struggles." When *close* combats take place in future between Cavalry and Infantry, the rifle will not be so much more effective than the musket, though it will undoubtedly be more formidable, from its greater accuracy in the hands of better instructed men; but it will be far more difficult for Cavalry to approach Infantry from a distance. Increased precision of fire from Infantry, extending over a greater range, will necessarily be very destructive to an advancing body of Cavalry. It has already been proved in numerous cases to be possible for Infantry to resist Cavalry with the old musket and bayonet, in square; and occasionally, a successful resistance has been made to them even by Infantry in line. Henceforth, if Cavalry attempt to charge a line of Infantry from a distance, which they will hardly do without being well supported by Infantry or Artillery fire, or by both, it will probably not be desirable in many cases for the Infantry to form square; but will be found more advantageous, if the troops can be trusted, that they should remain in line, and thus develope the greatest amount of fire upon the Cavalry during their charge. For attacking troops in motion, and especially for the destruction of Infantry in retreat, Cavalry will still retain much of their importance, though they may be expected to suffer considerably more from their enemies' fire in all cases than they have hitherto done; and, when not specially employed, they must be kept well out of reach, or out of sight, of hostile skirmishers.

Such being, apparently, the principal changes to be anticipated in the relation of the three arms to each other, when instructed riflemen acquire experience in the field, when improved guns are brought into use, and when these meet in opposing armies, I propose now to offer a few remarks on an important branch of the subject, which I hope will not be altogether unacceptable to my brother officers.

In the 2nd Vol. of the First Series of the Royal Engineer Professional Papers, there is a valuable contribution from the late distinguished and lamented Sir William Reid, entitled:—"On Entrenchments as Supports in Battle, and on the necessity of completing the Military Organization of the Royal Engineers," in which that officer has pointed out, both the importance of entrenchments as supports in the defensive battles in which British troops have so often and so successfully been engaged, and also the advantage that might be derived from them in many cases of offensive operations.

A peculiar interest attaches to this Paper at the present time, and if I do no more than re-direct attention to it, I shall not have laboured in vain; but I hope further to apply the principles which Sir William Reid has so truly enunciated to the altered circumstances that have since arisen, in a manner that may not be without some good effect.

Neglecting the more extreme ranges, it may be roughly stated that individual soldiers will now be enabled to deal out destruction to an enemy's masses with tolerable certainty at a distance of half a mile, and that, when the nature of the ground will admit of it, Field Artillery will be able to produce similar effects at two or three times that distance. Supposing the skirmishers and the Artillery on both sides to be equally efficient, it is evident that each party will be able to employ a system of distant molestation against the other, even though a general action be not immediately intended on either side, whenever two armies approach sufficiently near to each other to admit of it.

Skilful skirmishers will have it in their power to harass an enemy in this manner without much exposing themselves, as also will isolated guns, or batteries, forming but a small object for an enemy's distant fire; and they will therefore have the means, on either side of two armies, of injuring the masses opposed to them to a great extent, whilst they will not be able to protect their own masses against each other, respectively.

The distance at which skirmishers may be employed without support is difficult to determine, being dependent upon a variety of circumstances. It has been stated at 300 yards, but it may now probably be increased beyond that distance in many cases; though it cannot be supposed that they could be pushed out to a distance that would enable them to keep off effectually the skirmishers, or, much less, the Artillery, of an enemy. As the supports would necessarily be in closer formations than the skirmishers themselves, these again would be more difficult to conceal, and would be more exposed to the enemy's fire; and there would be a similar difficulty, though in a less degree, in pushing out the supports of the skirmishers as in protecting the masses themselves.

These are matters for interesting and important discussion; but there is one truth clearly discernible, in consequence of the increased power that skirmishers and Artillery have acquired. All masses of troops in the presence of the enemy, even when not drawn up in line of battle, are now in want of protection from distant fire, to an extent that has never yet been experienced. One of the first considerations in future with a General (and particularly with one at the head of an invading army, in a country where the rifle is much employed by the people), will be how he can best protect his masses from hostile skirmishers, and from distant Artillery fire.

Troops will require to be screened, or otherwise protected, now, from an enemy's fire, not only for the sake of saving their lives, but also in order to give them confidence. Hidden, or suspected dangers, are often more demoralizing in their effects upon soldiers than those which can be seen. A body of men who would rejoice to see superior numbers of their enemies 30 or 40 yards in front of them, and would charge them with cheerful shouts, would shrink immediately afterwards from advancing over a spot in which they suspected the presence of a mine; and hence arises one great reason for the necessity of protecting troops from hidden sharpshooters and distant Artillery. A good choice of position will of course do much in this way; but an army is often obliged to fight in a position which it is necessary for strategical reasons to hold, and which is not exactly such as the General would otherwise have selected. The best of positions, however advantageous in many respects, will not afford all the protection that now becomes necessary, and in many there will be an amount of exposure highly detrimental.

It is clear that the soldier can carry nothing about with him which would protect him from the effects of his enemy's muskets, and still less from hostile artillery; and that his only security must lie in the interposition of natural or artificial screens, such as he may find ready to his hand, between himself and his hidden or distant foes. In this emergency, the ready aid of the Engineer will become invaluable; and it is not too much to say, that the army which can be most speedily entrenched in the position which it is called upon to take up, will possess an advantage under these altered circumstances over its enemies, which will be only second to that of the possession of the best artillerists and marksmen.

It therefore becomes a question of the highest importance to the Engineer to consider beforehand what means are at his disposal for, and what system he should adopt in carrying out these urgent requirements. It will be too late to do so when they are to be executed.

Such works will have to be decided on, traced, superintended, and executed, in the shortest possible time, and in the most advantageous manner with reference to all possible subsequent operations; and their successful construction, at any time a matter of sufficient difficulty, will become an impossibility unless the Engineer has very large means at his disposal.

With the small force of Sappers that now usually accompanies a British army, and the small amount of instruction that has been hitherto afforded to the Infantry, it would require a longer time than could be generally afforded, effectually to intrench an average position; and the principles that should govern such an operation appear hitherto, if we may judge by the little that has been written on the subject,* to have been less attended to by the British Engineer than any other part of his duties, in consequence, no doubt, of the limited demands for such works that have been made upon him. But works of this sort would require, perhaps, to be performed in a night, in anticipation of a morning attack; and it is essential that these principles should be thoroughly understood, and practically taught, so that their application may be attended with the least possible delay. And here it may be observed, that, as has been the case formerly, so also in future, sufficient time will frequently be afforded for such operations if ample means be provided for carrying them out; because the increased difficulty of reconnaissance will often render necessary the delay of a projected attack, just as much as an increased power of intrenching in the defence will render it desirable to expedite it.

In considering the principles that should govern such operations, it would appear that there are two descriptions of works required for entrenching a position, viz., those in which security against assault is all-important, and those which must be constructed so as not to obstruct the forward movement, or the manœuvres, of the troops defending them. The former will be combined with houses, villages, and all those similar objects, which have been found so important, and have been so warmly contended for in former battles; the latter will be adapted to the larger features of the site, to the undulations of the ground, and to the hedge-rows, walls, banks, and other obstacles, which have of themselves afforded so much protection on past occasions to British Infantry, as well as other troops. The former will be constructed with the usual parapet and ditch, and any other obstacles that can be procured, and will be so laid out as to receive flank defence from their own parapets, from neighbouring works, or from both; the latter will be formed more like the parallels for a siege, with steps, or slopes, so as to facilitate ingress and egress; and they will be so laid out as to afford a maximum of cross fire upon the approaches in front of them; but flank defence, such as is required in other works, will not be necessary for their faces. The former will generally be constructed with indented parapets, in order that flank defence may be obtained for their different parts; the latter will possess no more irregularities of outline than are demanded by the site, as the troops behind them will be expected, not to await their assailants under cover of their works, but to leave their defences, and to charge any enemy who may persevere, in spite of the fire that they receive during their advance, in approaching them. The great merit of the former will be in their completeness,

* The third chapter of Sir John Jones's "Memoranda relative to the lines of Torres Vedras," is the best authority, besides Sir William Reid's paper, above quoted, to which I am able to refer. It is hoped that the reader will peruse this important chapter—the result of much experience and reflection—in connection with the present paper; considering, in doing so, how far the altered circumstances of improved weapons would have caused the author, could he have foreseen them, to modify the opinions therein expressed, and with how much more force many of them apply to the future, even than to the past.—H.T.

and the degree of security afforded by the materials that can be procured; the chief merits of the latter will be in direct proportion to their efficiency, to their adaptation to the features of the ground, and to the general requirements of the position, and inversely as the quantity of labour expended in their execution. The former must be increased in strength according to the importance of the position which they defend, and the time and means at command; the latter must excel in simplicity to the utmost extent that is consistent with effective protection. With the former, it may be repeated, prolonged defence is the main object; with the latter, facility for offensive operations, for development of fire, and for necessary manœuvres, are the points of most importance.

These two descriptions of works are thus respectively applicable, the former to any advanced posts before which it is desirable to keep an enemy in check and under fire, to the important points of a position which it is necessary to defend to the utmost, and to works provided for the security of the flanks, which must be maintained at any cost; the latter to all those other parts of a position in which screens or parapets are required, either to conceal the masses or to protect the troops in position from the fire of the enemy. They require to be applied in a somewhat different manner, according as a General proposes to commence the attack or to remain on the defensive. They may sometimes be employed by the assailants as supports from which their attacks may be conducted, in which their reserves will be sheltered, and to which they can retreat in case of disaster; and by those who are on the defensive as a means of inflicting the greatest loss upon their enemy with the smallest risk to themselves, and of preserving their position intact, and themselves in the highest state of efficiency for subsequent operations.

It will be important, in many cases, so to design the more defensible works, and particularly the advanced works, as to prevent them, as far as possible, from becoming useful to the enemy in the event of their capture. This will be done, either by leaving them open to a fire from the rear, or by so placing them that they may be commanded from other points, according to circumstances. And, in like manner, it will be necessary for the assailants to have the means of reversing the defences of any posts of which they may gain possession, and in the shortest possible time. It may be expected that as the difficulty of an attack in front will materially increase, so there will be more manœuvring previously to the assault of a position; and that as the fire at long ranges must be confined to daylight, so there will be more fighting as well as more entrenching carried on in darkness, or at times when the light is defective, than has hitherto been the case. It will therefore be desirable to pay additional attention to the security of the flanks of a position, and to the provision of means of artificial illumination. The employment of the latter may now be advantageously increased, as well in field as in siege operations.

As examples of impromptu entrenchments, those of the Romans are most remarkable in ancient, and those of the Russians in modern times. Pultawa, Borodino, and Sebastopol are well known instances, amongst others, in which they have been advantageously employed by Russian Commanders. In the prolonged operations of the Crimea, sufficiently remarkable contrasts have been exhibited, as on many previous occasions, in illustration, on the one hand, of the advantages which are afforded by the possession of ample supplies of men and means, and, on the other, of the difficulties and dangers which must be encountered for want of them. May we, as a nation, benefit more by the lessons there received than we have done by former ones!

I will venture now briefly to consider what will be the probable mode of action, when modern improvements are fully brought into play, in the simplest form, in future battles. This must be, of course, to a certain extent, matter of speculation, though not so much so as it might appear to be at first sight. By carefully considering the principles by which Commanders have heretofore been influenced, and the modes of fighting that they have adopted under other circumstances, and by applying to these the additional considerations arising out of the increased powers of modern weapons, it becomes possible to obtain a fair general idea of the forms which future combats will assume, or, at least, such an idea as will enable us to see much more clearly the preparations that are required to be made with a view to future success, than if no such speculations were entertained. At all events, such considerations serve to place vividly before the mind the practical effects of the new weapons; and, in fact, this is just the process which every Commander and every Engineer must, or ought, to perform, before they lead or accompany a body of men, armed with the new weapons, against an enemy similarly equipped.

That General who can best foresee the precautions required, the operations suited, and the means adapted to these altered circumstances, will have a great advantage over his opponent,—the same advantage that has been derived from similar powers of perception by all great Generals, from Miltiades to Wellington, from Alexander to Napoleon.

When two armies approach each other, then, under these circumstances, they will, in all probability, immediately proceed to improve the positions which they respectively select, and to entrench themselves, to the best of their power, the one with a view more particularly to offensive, the other to defensive operations. The assailants will principally devote their attention to the construction of batteries for their guns, or for such of them as it may be necessary to employ at shorter ranges, trenches for their infantry, and field forts, redoubts, or strong posts, for the important points of their position; and they will so lay these out as to afford support to their advance, at the same time that they can be made available for the protection of their retreat, in the event of subsequent disaster. The defenders will provide carefully for the security of their flanks, the concentration of their fire upon the approaches to their position, the defence of their advanced posts and their decisive points, the concealment of their troops from the enemy's fire, and the means of advancing from under cover without obstruction at the proper moment.*

It may be expected that, in making their attack, the assailants will first destroy the defences of their opponents to the best of their power, by means of shot and shells fired at low angles, and that they will next send forth an extended line of skirmishers, whose duty it will be to harass all the enemy's masses that may be exposed to their view, to drive in the opposing skirmishers, and, when they arrive sufficiently near to them, to keep their foes behind their earthworks. Employing shells fired at high angles, to harass the defenders behind their parapets and trenches, the assailants will then despatch their masses in lines, or columns, or an admixture of the two, according to the character and disposition of the troops, and the nature of the ground; and they will endeavour to storm the entrenchments opposed to them.

Unless the fire of the defenders be well kept under, the loss of the assailants during the advance will necessarily be very great, and they will be but ill able to stand a charge at the end of it; and if they be unsuccessful their loss during the retreat will not be less. Exposed in both instances to a fire of murderous accuracy, over a prolonged period, while traversing half a mile of ground, or more or less according to circumstances, decisive results will have been produced upon them, during the mere advance and retreat, such as have not hitherto been imagined.

Then will be found the main advantage of their guns in position, and of such works as they may have thrown up before their attack. The better suited their works are to

* Sir William Reid, in the article above quoted, remarks that "defensive positions are best maintained by offensive actions, and defences, when it is possible, should be so constructed as to admit of the defenders coming forward *in line*, to meet, and to attack in turn, the assailants."—Ed.

receive them, and their artillery to protect them, under these circumstances, the more capable will they be of retrieving the day, or of saving themselves from utter defeat after such severe losses.

Should the first assault prove successful, then there would be either a second line of the defenders, uncovered, or else a second line of entrenchments, to encounter; and here the new weapons would not make so much difference as before in the proceedings to be adopted. The principal alterations would be, that the assailants would be liable to be taken in flank from suitable positions at greater distances from the part attacked, and that they would find greater difficulty in forcing the defences of any important points of the position that might be strongly intrenched, and supplied with flank defences, in consequence of the greater precision of the fire with which these would be defended. But until it shall be found possible to adopt breach-loading weapons, the new rifles will not have anything like the same advantage over the old musket at close quarters as they will possess at greater distances. When the use of these more rapidly loading muskets shall become general, then will the assault of entrenched positions indeed be difficult, and then will all combats between uncovered troops be short, sharp, and decisive.

The duties of cavalry in such a combat will probably be confined to action on the flanks of the assailants, or against the enemy's cavalry, or to movements in which increased rapidity may be required, and which can be well supported by infantry and artillery fire.

The part to be played by artillery in future battles I have already referred to. Shells will apparently be their most effective missiles, fired at low angles for ruining defences, and at high angles for driving the defenders from behind them, with all the precision that can be obtained from the latest improvements. The rule that has hitherto been in force, under which artillery has been enjoined to fire at the troops, rather than at the artillery of the enemy, will now, perhaps, be to a great extent abrogated. The artillery of the defending army will be usefully employed in opposing and silencing, as far as possible, the artillery of the assailants; and a portion of the latter will necessarily be told off to act against the former. Their duties in these respects, and in ruining an enemy's defences, will become so important, that they will be less available during an action for employing shot and shells against masses of troops, either at long or short ranges; though they will, of course, with the increased effects that may be expected from them, be most formidable for these purposes at much longer ranges than heretofore, when the troops are exposed, and when the nature of the ground admits of such ranges being employed. They will also continue to assist, on the part of the defenders, by means of such fire as they can bring to bear, in the destruction of the assaulting parties, and to employ grape and canister, from under cover, against all masses that come within 300 yards or so of them.

It is not to be expected that when first rifled musket meets rifled musket, and rifled gun meets rifled gun in future warfare, such important changes as I have here sketched out will at once be brought to bear. It is probable, on the contrary, that time and much loss will be required to demonstrate their necessity, before entrenchments will be thus fully employed. Generals, officers, and men will alike have to feel their way to the full and judicious employment of their new rifles, and the Artillery to that of the new guns that are being constructed. The most recent Indian experience will be of great advantage to British troops, as Algerian experience will have been to French ones; but the conflict of improved weapons in instructed hands on both sides has its lessons yet to teach. Speculations, such as I have here attempted, may fall wide of the mark, and may be rendered futile by the light of future experience; but they are the only means which we have at present of arriving at conclusions; and I trust that some of my brother officers who are much more capable of discussing this subject, may be induced to contribute to its elucidation.

It will be admitted, at all events, that the tendency of modern improvements will be in the direction which I have indicated, although time will probably be required to give development to new systems of action. The gradual progress in this direction will perhaps be somewhat as follows :—Cover and concealment will be found, by fatal experience, to be more and more necessary. Entrenchments will be more generally formed in the field. Great advantages will be found in some cases to have been obtained in consequence of their employment. *Entrenching habits* will be formed, increased means of constructing entrenchments will be afforded, and, in time, they will come into general use.

As far as can be foreseen, according to the lights which we now possess, it would in fact appear, that these principles and applications of the Engineer's art, which have hitherto been principally confined to siege operations, will in future be introduced more and more extensively into the field ; that as rifles, both large and small, come more and more into efficient use, earthen parapets and earthen screens, as auxiliaries to natural obstacles, will be increasingly demanded for the soldier's protection ; and that Generals must pay more attention to engineering, and Engineers to tactics.

These are questions of the highest importance to the Engineer. It is for him to consider them deeply, and to be prepared for that which will be required of him in future. It will be no sufficient reply, when work is demanded from him hereafter, to say that soldiers lack instruction, that sappers are not sufficiently numerous, or that proper supplies of tools are wanting. He may then be properly informed that he ought to have exercised more foresight, and have represented the necessity for the requisite preparations at a time when they could easily have been made. If he fairly states these things beforehand, gives proper reasons for them, and makes such exertions to obtain them as he becomingly can, then he is relieved from responsibility ; but if he fails to do so, then must he be considered as principally accountable for any failure that may ensue from the want of them.

It must also be remembered that the more the number of our Sappers is increased, and the more our Infantry officers and men are trained in field engineering, the more will it become necessary to provide transport for tools and stores, on a scale commensurate with the work that will require to be performed. Upon this point it is hardly necessary to do more than refer to the Notes, extracted from Sir John Jones's " Sieges in Spain," and printed in the 2nd Vol. of the old series of the Professional Papers, next in order to the Paper of Sir William Reid to which I have alluded.

Sir John Jones mentions the extraordinary circumstance, that the superb expedition, which was fitted out at so much expense in 1809, to effect an object dependent upon the speedy reduction of Flushing, Antwerp, and other fortified places, was actually sent from England without any means of carrying forward the engineers' stores, "although some thousand horses were embarked for other purposes ;" and he says : " It would be useless to recall the many instances in the early part of the last war in which corps could not take advantage of various defensive expedients that presented themselves, such as destroying roads, blowing up bridges, retrenching posts, &c., for want of a field establishment of intrenching and miners' tools moving with them."

He alludes to the circumstance that although Engineers without their tools and stores are in a similar position to troops without ammunition, or Artillery without guns, yet there was not the same provision made during the Peninsular war, until after the Duke of Wellington experienced the absolute necessity for it in 1811, for the transport of engineer stores, like that connected with other departments. He refers to, and gives the details of, the spendid engineer equipment organized by Napoleon in that year. He shows what trifling means, comparatively speaking, are required, even to provide engineer transport on a liberal scale ; that fifty carts and fifty horses, laden with engineer stores, would have converted positive deficiency into absolute abundance, at the several sieges in the Peninsula, where so much loss was experienced from the want of them; and that 200 horses for the engineer establishment, as against 10,000 which were actually employed in the service of guns and ammunition, would have amply supplied the army with all that was necessary.

An engineer train has lately been wisely formed in this country, but it will have to be expanded in the event of a war occurring, and adapted to new circumstances. Sir John Jones's remarks are worthy of attentive perusal at the present time; but his estimates will have to be increased, in proportion as the Engineers are required to supply tools to the Infantry for ordinary use in the field, as well as for sieges or other special cases, and in proportion to the increase that may be made in their own numbers on active service.

In any sieges that we may be called upon in future to undertake, it is of the utmost importance that practical workmen should be employed in great numbers, and should be provided with ample means, not only of tools, but also of gabions and other entrenching materials, to enable them to get under cover in the shortest possible time. Without such means, it will be next to impossible to carry on any works against an efficient garrison provided with improved rifles and proper means of artificial illumination.

If it should ever become necessary to oppose a hostile army on British soil, vast numbers of volunteer riflemen, to hover about the flanks and rear of the invaders, and, in conjunction with the regular troops and militia, to dispute the ground in their front mile by mile, from a series of entrenchments formed, as required, by sufficient numbers of well-trained sappers, are the instruments that would be found most effectual for purposes of national defence.

In fine, for all future operations, offensive or defensive, at home or abroad, an infantry instructed in field engineering, a greatly augmented force of sappers, and ample means of transport for tools and stores, are amongst the principal means and appliances that have become of increased importance, in consequence of the vast improvements that modern skill has effected in the most destructive weapons of war.

PAPER XXI.

Account of the Floating Bridge contrived by General Buckmeyer, and thrown across the Danube, near Galatz, in March, 1854, by the Russian Army under Prince Paskiewitch.

The construction of this bridge is shown in the accompanying Plate. Each pier was formed of seven logs, contiguous to each other, the thicker ends directed up stream and pointed as represented in the Plan. Two piers were formed into a raft, the interval being six or seven feet. The rafts, so formed, were at like intervals, and so connected by baulks as to allow of a motion adequate to the very slight movement which these long rafts could acquire from the small waves of the Danube.

Each pier had an anchor up stream, the cable being made fast to a small wooden capstan fixed near the ends of the logs. There was also one anchor down stream for each raft, the cable being fixed to a small capstan on a platform between the piers.

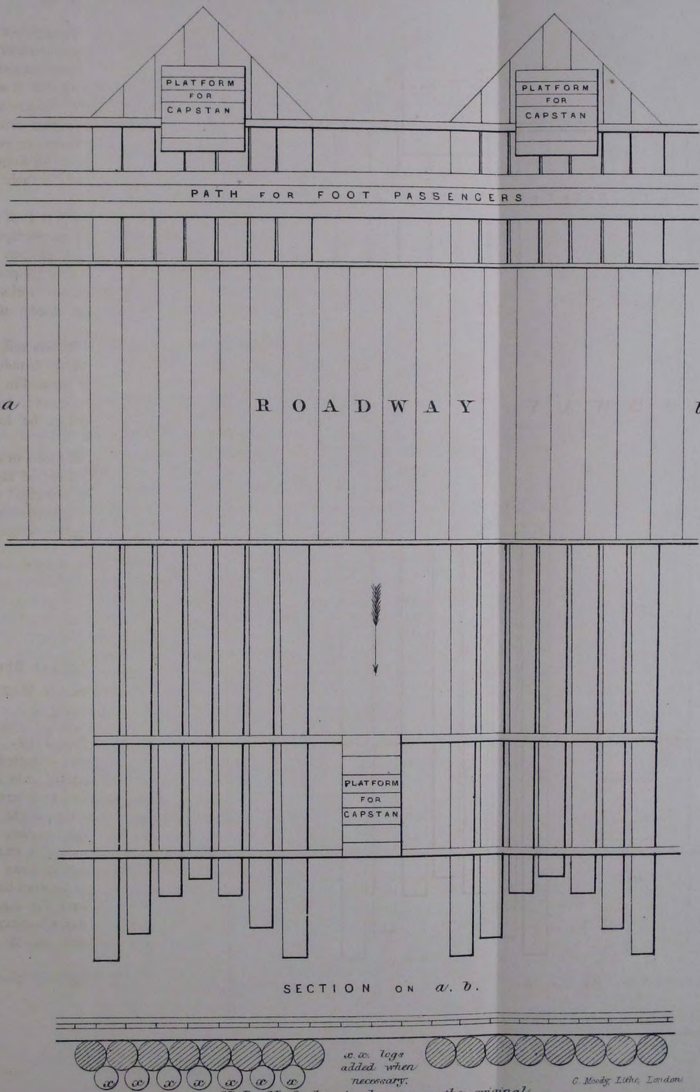
The roadway (14 feet wide) was placed with its centre, not over the centres of the logs, but over the centre of floatation; and, in addition, there was a footway the whole length of the bridge, about 2½ feet wide, between the carriage-way and the large ends of the logs.

When the logs were small and insufficient, supplemental logs were placed in the intervals under them, as shewn in the sketch.

PLAN OF RAFT-BRIDGE

THROWN ACROSS THE DANUBE, NEAR GALATZ, IN MARCH, 1854

BY THE RUSSIANS.



N. B. No Scale is drawn on the original.

C. Moody, Litho, London.

PAPER XXII.

EXTRACTS FROM AN ANALYSIS AND COMPARISON OF THE FRENCH AND GERMAN SYSTEMS OF FORTIFICATION, PUBLISHED IN THE "SPANISH ROYAL ENGINEERS' ANNUAL PAPERS,"

BY DON SALVADOR CLAVIJO, COMMANDANT OF ENGINEERS.

TRANSLATED BY CAPTAIN HUTCHINSON, ROYAL ENGINEERS.

MODERN GERMAN FORTIFICATION.

Under this head are comprehended the principles which have served as the basis of the various traces adopted in the newly constructed fortresses scattered over the different states of Germany, and which have also been followed in repairing some and enlarging others of the previously existing fortifications of the country. Up to the present time there have been few military writers who have occupied themselves with this subject, and even these few have not treated it under its general aspect, but have very much confined themselves to the explanation and consideration of particular works. The treatise of Colonel Humfrey is designed to describe Coblentz only, and although the author has done this completely, and has accompanied his memoir with many exact plans and details, the observations in which he pronounces judgment upon the defensive value of this fortress cannot be considered sufficient for forming one upon the system generally; it would be like attempting to appreciate the whole of Montalembert's ideas from a review of only one of his different systems.

Captain Madelaine, of the French service, making use of the explanations and plans of Colonel Humfrey, has made an analysis of this same fortress, and confining himself especially to Fort Alexander, arrives at a result diametrically opposite to that of the English author, computing the defensive value of this work and of the whole fortress much below that of bastioned fortifications. The different memoirs which Maurice de Sellon has lately published, are very far, in my opinion, from serving as explanations of the system, since, without fixing either the principles or entering into the spirit of this new style of fortification, he appears rather to turn his attention to calculating the defensive strength of some particular traces as compared with the bastioned trace, so that, although the results he arrives at may be correct (which, as will be seen farther on, I am far from granting) they do not suffice to prove whether the German novelties are or are not a real advance in the art of fortification.

The German Engineers, whose works could alone be taken as safe guides on this subject, seem to have observed very great silence, taking no notice either of the impassioned eulogies of Humfrey or the exaggerated criticisms of Madelaine and Maurice; one only (as far as I know), General Brèze, of the Prussian Engineers, has written a

* For extracts from this see the article on Permanent Fortification in the British Aide-Memoire.—ED.

memoir entitled – "The origin and nature of the new system of Fortification in Germany;"* but this work, full of general considerations upon the subject, is not sufficient (nor could the author have intended it to be) to give a complete knowledge of the system. Sprung, as this is in a great measure, from the systems of Montalembert, it gives facility, like them, for very varied combinations, and in order to arrive at a due appreciation of its great principles, it is necessary to examine in what way they have been combined in each particular case, which of them predominates, and with what limitations any particular one may be admitted. For this purpose, in making an extended examination of the new German fortresses, it may be readily believed that the same maxims have not been followed in all of them, and that their Engineers are not entirely agreed about the choice of a type or front which shall represent the most approved combination that can be adopted; in like manner the different characters of the ground do not suffice to account for the variations of form, since these differences occur not only in the general plan of a place, according to the purpose it is intended to serve in the defensive system of the country and for other important objects, but the nature of different works in the same fortress varies according to the special objects which they are intended to accomplish. Thus Coblentz differs from Posen, and moreover in the latter the traces adopted for the fronts of the town and for those of the citadel are quite distinct. Even greater differences are observable in comparing the fortresses of the different kingdoms of the Confederation, and to be convinced of this it is only necessary to glance over the plans of Posen, Rastadt, Ulm, Ingoldstadt and others. The difficulty of accounting for these differences of trace has induced some French writers to attribute want of unanimity to the advocates of this system, since (according to them) one of such a number of combinations must be the best, and this one should be always followed.

If this can be said in reference merely to the fortresses of the Germanic Confederation, the plan and projects for which may reasonably be supposed to have been approved by a conference of military authorities, how much greater diversity of ideas would be encountered in examining the modern fortresses of other countries which have adopted the system followed in Germany; for it is not this latter country alone, which, in abandoning the bastioned system, has sought in new principles the only means of restoring to fortified places their former value; almost all the powers of Europe, except France, which have been able to devote large sums of money to the construction of new fortresses, and to the repair of old ones, have followed the road marked out by the German Engineers; and hence has resulted a new school of fortification supported by the opinion of many Engineers who were eye-witnesses of the insufficiency of the old fortresses in the last continental wars, but opposed by all the well-earned fame of the French Engineers, and also by the fact that it has not yet received the sanction of the experience of war, an indispensable element for a sound analysis. These considerations will justify us in entering into some details which may up to a certain point appear foreign to the purpose in hand. The investigation of this system will comprehend :—

1st. The description of the elementary works of a front, as kaponiers, batteries of all kinds, defensive barracks, &c.

2nd. Construction of an independent work; defence of which it is capable.

3rd. Description of the traces most generally employed, and application to aquatic sites.

4th. General construction of a fortress; outline of the general plan of some of the most important ones.

5. Attack of the system, and its analysis.

ELEMENTARY WORKS OF A FRONT. KAPONIERS, BATTERIES, DEFENSIVE BARRACKS.

ESCARP AND COUNTERSCARP WALLS.—The escarp walls are of three kinds—1st, Ordinary retaining walls; 2nd, Counter-arched revetments; 3rd, Detached or independent walls.

The 2nd and 3rd kinds are those most generally employed in Germany.

(Here follow rules for the construction of revetments, and after alluding to the Woolwich practice against Carnot's wall, the author continues thus:)—There are many who think that in like manner as the detached wall in the Woolwich experiments* was destroyed by a pitching fire, so the front wall of a casemated battery, notwithstanding the increased resistance afforded by its piers and arches, would be breached, attributing a large part of the result to the vibration which the wall suffers, vibrations which are destroyed or considerably lessened when the earth comes in contact with the back of the wall. There are others, on the contrary, who affirm that the thrust of the earth, increasing with the vibrations, will only hasten the fall of the ordinary revetment, and that consequently this mode of attack would be equally prejudicial to the ordinary walls of a bastioned fortress, which would not only have the defences of its ramparts destroyed by distant ricochet fire, but also have its walls breached by the same. Fallot and other French writers do not hesitate to assert that ordinary escarp walls are to be regarded as secure against this fire, notwithstanding that the former records the fact of a considerable breach having been opened in the face of a bastion by the fire of a ricochet battery intended for the face of one of the ravelins, at the siege of Alessandria by the Austrians in 1800. Zastrow, without entering largely upon this question, indicates a contrary opinion. With respect to two walls of slight thickness, it appears evident that the one backed with earth will offer the greater resistance; but can the same be said of walls of great thickness which artillery can destroy only by fracturing them piece by piece? Experience is the only means of deciding this question, and further on we shall have occasion to record the experiments which have been made, and to notice the nature of the attack founded upon them.

MORTAR BATTERIES.†—These batteries are placed in the two following positions—1st, in the interior of a work behind its terrepleins, and 2nd, in the salient angles under the terreplein itself. These batteries, like those of Carnot, are intended to inundate with showers of projectiles the works of the besieger on the glacis. The arches are inclined upwards towards the exterior, in order that the fire may not injure the masonry; a narrow ditch is sometimes placed in front for rolling the enemy's shells into. In connection with the batteries in the salient angles casemated guard-houses are often constructed at the junctions of the two escarps; these cover the batteries from all direct fire, court-yards on the same level as the floors of the batteries, and as wide as the fire of the mortars requires, being left between the buildings.

KAPONIERS.—(After describing their general form the author remarks)—As these works are exposed to the fire of the counter-batteries, they are made so that the doors in the interior walls of each flank do not correspond, thus avoiding the danger of a projectile, after passing through an embrasure in one flank, hitting the gunners in the opposite casemate of the other flank.

Sometimes a mortar battery is constructed at the salient angle of the kaponier. Rastadt offers examples of this arrangement, the batteries being on the first floor.

* The Report on these experiments will be found at page 45 of the 2nd Volume of the old series of these Papers.—ED.

† The details of most of the works mentioned in this Paper are given in the 2nd Vol. of the old series of Professional Papers. See pp. 51 to 74.—ED.

This fact is mentioned as contrasting with the positive assertion of Fallot, of the impossibility of constructing casemates capable of resisting the concussion from the discharge of mortars or even howitzers, the batteries in question having been frequently fired from without the arches having suffered in the least.

DEFENSIBLE BARRACKS.—The general form of these buildings is the most simple possible, and the most suitable to their object. They consist of a series of rooms separated by walls at right angles to the perimeter of the building; these walls carry the bomb-proof arches which cover the different floors; and parallel to the exterior wall runs another, separating the dwelling rooms from a gallery in which the artillery is placed. The breadth of this gallery varies between 16 and 24 feet, according to the importance of the barrack. The exterior wall, in which there are no openings excepting the embrasures, is from 7 to 8 feet thick, but the party walls are much thinner; the thickness of the bomb-proof arches, which have a span of about 15 feet, is from 3 to 3½ feet; when however they are intended only as floors 1½ feet is considered sufficient for supporting the weight of artillery. The barracks are generally three stories high, the lowest one being half under ground; the roof consists of a terrace surrounded by a parapet wall, and is intended for guns. The height of each floor is from 10 to 11 feet; and that of the whole building is regulated by the condition that it must be perfectly covered by the parapets of the work to which it serves as a keep. Sometimes these barracks consist of four or five stories, as at the citadel of Posen, where the distance of the barrack from the work, and a fall in the ground inside, allow of its being covered, notwithstanding its height.

INTERIOR REDOUBTS.—The barracks above described receive this name when situated, for example, in the gorge of a lunette, to which they serve as a retrenchment. The following is the general mode of connection between the barrack and the work. A narrow ditch surrounds the former, in the interior of the fort, so that the entrance to the barrack, by a bridge over the ditch at the gorge, is independent of the entrance to the fort. This ditch is defended either by an escarp gallery for musketry or by small kaponiers. From the lower story of the barrack, or from the kaponiers, galleries are carried across and below the bottom of the ditch, terminating in countermines formed under the terreplein of the fort.

POWDER MAGAZINES.—Those here referred to are only the small permanent magazines constructed under the terrepleins, which replace with much advantage the timber ones ordinarily constructed during the first days of a siege. The only consideration which can militate against their use is the difficulty of keeping them dry, and even this has been completely overcome. The magazine is surrounded by an arched space into which ventilators open, and this space is connected by other ventilators with the postern or entrance gallery, so that a complete current of air is obtained. The exterior surface of the wall of this arched space is as carefully treated as the extrados of the arch.

INDEPENDENT WORKS.—Under this title are comprehended those works which unite in themselves all the means necessary for their own defence, without dependence upon collateral works or works in rear. They enter in various ways into the formation of a defensive position, sometimes occupying the most salient and important points, and if they are connected by curtains, which receive flank defence from them, a complete enceinte is formed, in which these works are the only points necessary to attack, as is the case at Ulm. By increasing the capacity, and consequently the defensive powers of these works, a small number of important points suffices for forming the base of the position, the large intervening spaces being closed by curtains which are of a much weaker character, inasmuch as their re-entering position, or other circumstances of locality, prevent their being attacked. Rastadt is an illustration of this. In other cases, as at Coblentz, they form a line with intervals, to which the fortifications of the city serve as a large citadel. Another very common use of them is to occupy points in the neighbourhood of a fortress, the possession of which is of importance to the defence, or, as at Cologne, to form an entrenched camp.

These works,* which may be regarded, in the system under consideration, as a fundamental portion of a fortified position, will be now described. Their formation is for the most part uniform, whatever the position they occupy, with the exception of those arrangements having reference to the reciprocal defence which they often afford each other.

1. The leading feature is a bomb-proof defensive barrack closed at the gorge, having generally two or three tiers of fire from casemates, and another on the platform of the building, from the parapet which surrounds it. The outline of its plan, sometimes round, at other times polygonal, depends upon that of the work to which it serves as a keep.

2. The barrack is surrounded by a work, the principal faces of which have ramparts, and the gorge of which consists of a simple wall: the form most commonly employed is that of a lunette with the barrack in its gorge. The extremities of the barrack project in rear of the gorge wall, for flanking its ditch, and when several of these works form a line, their mutual defence is principally derived from the artillery of these projecting portions of the barracks. This is very important, since without this provision there would be no reciprocal or flanking defence, save that derived from the uncovered artillery on the terrepleins of the faces and flanks, a mode of defence not in accordance with the spirit of this system.

3. Between the terreplein of the work and the barrack there is a space for the accommodation of the requisite garrison for the former, and for a narrow ditch which surrounds the latter; this ditch is generally flanked by kaponiers for musketry, communicating with the basement of the barrack.

The profiles of the work and barrack must be so arranged that the masonry of the latter is perfectly covered by the parapets of the former, a condition most easily fulfilled by selecting for the barrack the lowest part of the position to be fortified.

The several tiers of fire in the barrack have the following objects:—1st. From the lowest a musketry fire is directed upon the interior of the work and hinders the approach to the counterscarp. 2nd. The two next tiers, armed with artillery, sweep the terreplein, oppose the assault of the breach, the besieger's lodgment upon it, and the construction of batteries against the barrack; on the lower of the two tiers howitzers are placed for obtaining a curved fire on the besieger's works. 3rd. Lastly, the upper platform commands the terreplein in front, and in conjunction with the exterior work, fires upon the besieger's first positions.

In the principal salient, and beneath or in rear of the terreplein, are placed batteries for small mortars, for shelling the works on the glacis, after the idea of Carnot. In the same salient, and upon the terreplein, a casemated traverse is erected for covering the adjoining faces from ricochet fire; this traverse, the walls of which are screened by the parapets, contains a howitzer battery for firing upon the most distant parts of the attack or upon the salients of the collateral works.

The ditches are flanked by kaponiers at the salients of the escarps, connected by posterns with the interior of the work; sometimes however the flanking works consist of counterscarp galleries.

* Plans and sections illustrating the principles of construction of these works will be found at Page 38, Vol. IX. of the old series of these Papers.—Ed.

The covered way is secured against assault by guard-houses, or casemated masonry redoubts, the walls of which are not visible above the crest of the glacis. The communication with these redoubts is maintained by subterraneous passages under the ditch.

One of the important features of these works consists of two sets of mines, one interior and the other exterior, with which they are generally provided. The exterior set usually commences at the counterscarp gallery, or sometimes at the escarp, and simply consists of galleries at right angles, or nearly so, to the perimeter of the work, and extending more or less under the glacis. The interior set commences at the kaponiers in the ditch of the barrack, from which galleries lead to mines placed under the terrepleins.

Under the terrepleins, and in those positions in which the scarps are least exposed to be breached, powder magazines are placed ; and when the work is of large size it is customary to have one of a greater capacity in the counterscarp at the gorge. Finally, right and left of the posterns and subterraneous communications, there are arched spaces for guard-rooms and stores.

Independent works have not always such a simple trace as that which has here been indicated. Sometimes they consist of crown works connected by branches with a large barrack, which serves as a redoubt. Such are the citadels of Posen and Ulm and the forts in the enceinte of Rastadt. Works thus constructed seem to have reached the highest degree of defensive power. It is impossible to crown the covered way either by assault or by systematic approach without first destroying the casemated redoubts. The counter-batteries must be executed in full view of the kaponiers, which, if uninjured, as may be supposed, possess as large or a larger number of pieces than themselves; the breach being formed and the assault made, the besieger will be obliged to form his first lodgements on it in front of and under the fire of the numerous artillery of the barrack, and to reach the latter he must engage in a subterraneous warfare in a restricted space well prepared for his reception.

These considerations are based upon the supposition that the besieger has at his command the same means, and no more, than are assumed in analyzing the bastioned system, that artillery cannot destroy masonry when it is well covered from the exterior, as is the case with the casemated redoubts in the covered way and the kaponiers in the ditches; in the same way it has been supposed that the defensive barrack cannot be injured until the rampart which surrounds it has been laid open, or the besieger has established himself upon it. It must also be observed that no reliance has been placed upon the uncovered artillery on the ramparts, which the besieger can ricochet and destroy from a distance. The Woolwich experiments, it is true, hardly warrant the correctness of the above assumptions, and for a complete analysis it would be necessary that experiments* should clearly show what would be the actual state of the masonry works, after having been subjected to the fire of a besieger's distant batteries. Leaving this question for the present, one further remark only will be made. If the defensive barracks can be destroyed without being seen, and if the bomb-proof kaponiers in the ditches, and the redoubts of the covered way, are in the same predicament, what would become of a bastioned fort whose terrepleins can be swept by ricochet fire, of the blindages for covering the artillery, of the barracks, and of the powder magazines placed in the gorges of the bastions? Why may it not also be supposed that breaches will be effected by distant fire in the flanks of *bastions*, and in their faces also, along the ditches of the ravelins?

* See Vol. VII of this Series, pp. 42 and 43.—Translator.

Reflections on the General Principles adopted in the New German Fortresses.

After describing what have been called the elements of this mode of fortification, it would appear natural to pass immediately to consider the trace of a front, and to observe in what way these elements enter into its construction ; but the fronts, or to speak more correctly, the methods of combining the works, are very far from being uniform, though they are all based upon the same general principles. In fact, by merely altering the relation in which these several elements enter into the composition of a system, and by giving prominence to one at the expense of the rest, a different form of trace is produced. If, for example, the trace which is adopted for the enceinte of a large place, defended by a numerous garrison, involves the use of wide and easy communications, it would not be suitable for that of a citadel, the defence of which must be of a much more passive character.

The universal use of casemated fire must be considered as one of the most important peculiarities of this system, whether as regards the artillery for flanking the ditches and opposing the construction of the besieger's counter-batteries, or that employed in the redoubts of the covered way and ravelin, and in the interior retrenchments. It is affirmed that two objects of the greatest importance are hereby gained : first, the artillery is preserved uninjured up to the time of the battery opening fire ; and secondly, by placing it in different tiers, a numerical superiority of pieces is obtained over those which the enemy can bring to bear upon them.

The immediate consequence of the adoption of this principle is the construction of the polygonal fronts according to the suggestions of Montalembert. This trace permits of doubling the length of the exterior side, although the lengths of the lines of defence are still regulated by the range of musketry ; and this circumstance is of the greatest importance, since in proportion as the exterior side increases so must the besieger extend his trenches, if he wishes really to envelop the fronts attacked and the collateral fronts. Bastioned fronts, with their large ravelins, form very deep re-entering angles, for the presumed object of detaining the besieger and causing him great losses; the latter, in order to overcome these difficulties, is obliged, in the first place, to silence the fire of the garrison, and as this fire also serves the purpose of flanking the ditches and of opposing the construction of the counter-batteries which protect the passage of the ditch, it follows either that the besieger must be supposed not to have the means of subduing the artillery of the place, and is obliged to stop half-way up the glacis, or that, when he has arrived at the counterscarp, the besieged has no other means of defence than the musket and bayonet. In the polygonal system, on the contrary, the defence of the ground outside is inferior,* and there is not the advantage of cross-fire for detaining the enemy, so that, as regards fire to the front, there is undoubted inferiority, notwithstanding the comparative freedom from ricochet ; but, on the other hand, when the besieger reaches the counterscarp the hitherto concealed artillery comes into action, and then commences the real defence. Another principle, then, of the system under discussion is the arrangement of the works with a special regard to the close defence, making that of the ground outside a secondary object. The advocates of the polygonal system base their arguments upon the constant experience of sieges ; their opponents, on the contrary, hope that experience will shortly prove that case-

* This is a mistake, for it is evident that if the polygonal fronts have ravelins of the same size as those of the bastioned fronts the fire of the former will be the most powerful, since they afford much more space for artillery on the ramparts of the body of the place.—Ed.

mated fire will neither be very efficacious nor capable of being preserved from injury as well as has been expected.

It has been stated that the adoption of the polygonal system is the immediate consequence of the general use of the fire from casemates, although Montalembert considers that the tenaille system is that which most naturally accommodates itself to a powerful reciprocal flanking defence. But as the prolongations of all its lines fall upon the besieger's trenches it is impossible to place any dependence upon the artillery placed upon the terrepleins, and it becomes necessary, as Montalembert proposed, to place the whole of it under bomb-proofs, while the terrepleins are destined only for musketry. This costly and nearly always impracticable arrangement, combined with that of casemates at right angles to one another at the re-entering angles, which cannot be regarded as secure from the accurate fire of modern artillery, leads to the conclusion that the tenailled trace must be regarded as essentially unfitted for fulfilling the conditions of defence.

As far as the present observations have extended, the principles of Montalembert, modified either to avoid some of the defects into which he has occasionally fallen, or in the arrangement of the details of each front, have been the only ones in question. But there is another prevailing idea or general principle in the modern German system which may be said to constitute a complete change in fortification, and which tends to confer upon fortified places quite a different character from that which they have hitherto possessed, and to place them more in harmony with the powers of modern armies and the advance of military science.

An extensive continuous enceinte, whatever the arrangement or system of its fronts, offers, throughout its extent, the same degree of resistance, or rather the same degree of weakness, since at each point the garrison must exercise the same amount of vigilance, but if the line to be fortified is occupied by strong works, which are able to afford each other mutual defence, and also contain in themselves all the means which their own defence requires, each of these becomes in fact one of the independent forts before described. The spaces between these works are closed by curtains or simple lines which may be regarded as unlikely to be attacked, either from their re-entering position, and the close defence which they receive from the collateral works, or still more from the fact that, if taken, the position of the enemy would be in no way improved, since he would remain in full view of very strong works still uninjured, the flanking fire of which would render his position untenable. Perhaps the enunciation of this principle in so general a manner may be considered as very hazardous and subject to grave objections ; but, like all other principles of fortification, it must be considered in all its bearings, for the formation of a correct judgment concerning its merits, and concerning the universality of its application ; its further analysis will therefore be reserved until the construction of some of the most important works has been described.

One of the advantages of adopting this principle is that the enceinte of a place may admit of large extension without the garrison strictly necessary for its defence being increased in equal proportion ; the place may well be considered secure from any sudden attack if the garrison is sufficient for the occupation of the points which have been assumed to be those upon which the defence really depends; and yet this same fortress can contain within it, when necessary, a large army, or serve as a base for any intended operation.

This system of fortification naturally requires that the different fronts should, when necessary, be capable of adaptation to the most active defence, and that the communications should be as broad and direct as possible, which latter is accomplished by placing them near to and under the protection of the flanking works.

THE DIFFERENT TRACES OF THE GERMAN SYSTEM.

The German Engineers reduce into a series of maxims the fundamental principles of all good fortification; some of these maxims have immediate reference to the particular mode of tracing a front, and others to the general features of the plan of a fortress; they are as follows:—

1. Simplicity of outline should be preserved, so that the defensive power may be in just proportion to the cost; and this principle leads to the adoption of polygonal fronts with central kaponiers.

2. Every line of a front ought to be adapted to the object which it is intended to fulfil.

3. To construct large fronts, by making use of central flanking kaponiers, thus obliging the besieger to construct very extensive works.

4. All the terrepleins of a work must be as far as possible secured from the effects of enfilade and ricochet fire.

5. To offer every facility for offensive movements, and for this purpose to reinforce the covered way with casemated redoubts or guard-houses.

6. The works charged with the special duty of flanking, or serving as interior retrenchments, must be under cover from distant fire, so that their artillery may remain uninjured up to the moment of its entering into action.

7. To give to the fortress an artillery superior to that of the attack, not during the first period of the siege, which is impossible, but during the last.

8. Each work should contain within itself all the elements necessary for its own defence.

9. The system adopted should render necessary successive attacks of all portions of the ground, and there should be no point which cannot be disputed with the enemy.

10. Every work or front should possess the barracks and bomb-proof buildings necessary for the garrison and munitions of war.

11. As a consequence of these maxims, a fortified position ought to consist of an assemblage of independent works provided with all the means of defence which each requires, but so arranged that all should contribute to the grand object in view.

The different traces employed in the modern German fortresses will now be explained, and it will be shown how far the general maxims just enumerated have been followed out in each. It has been already stated that they are very varied, and it may almost be asserted that there are no two places in which the same have been employed; this difference of tracing is still more evident on comparing the works erected in the different states of the Confederation.

BAVARIA AND WÜRTEMBERG.

FRONTS OF THE FORTRESS OF ULM.—This fortress consists of two parts, of very different construction; the one belonging to the kingdom of Würtemberg, on the left bank of the Danube, occupies very irregular ground, and contains most of the population. The other part, in Bavaria, stands upon a perfectly level site, and is a large bridge-head covering the suburb and the bridge. These differences of site have given rise to quite distinct methods of fortification; and the following remarks refer only to the works in Würtemberg. The whole of this enceinte may justly be regarded as a series of connected works, occupying the most commanding points of the position, care being taken that the intervals between them are such as to permit of reciprocal defence. The escarps of these works have two tiers of musketry fire, the lower one from a gallery formed by arches "en décharge," and the upper from a "chemin des rondes," 2 or 3 feet above the arches. The exterior slope terminates in the "chemin des rondes," and has several berms on account of its great height. On the level of the "chemin des rondes" there is a battery for four mortars, covered by a wall in front, against which rests a mass of earth; the battery is formed of two galleries, the one in front containing the pieces, the other facilitating their service.

A space is prepared on the terreplein of the salient angle for 4 or 5 heavy pieces, and a blindage is intended to be formed over these guns at the commencement of the attack; this would also serve as a traverse to both faces.

The gorge is closed by a loopholed wall, flanked by a defensive barrack, semi-circular in form, with a ditch and small kaponiers for its flank defence. The relief of the terreplein is sufficient to allow of the barrack having three stories, the lowest one for musketry, and the two upper for artillery; in addition to these there is another battery on the terreplein, serving as a cavalier against the first works of the attack.

A system of counter-mines, similar to what has been already described, commences at the kaponiers of the barrack.

The curtains run from the angle of the shoulder of one bastion to the next, so that the flanks of these latter do not defend the foot of the escarp, but, as an equivalent for this, they sweep the whole of the terrepleins of the curtains, an object of at least as much importance as the former, since it is not less important to oppose the besieger's first lodgments on the breach than to resist his passage of the ditch. The curtains are separated by a ditch from the flanking works, and the whole of the ditches are provided with flank defence by a judicious arrangement of kaponiers.*

Prussia.

Front of the Enceinte of the Town of Posen.—The length of the exterior side is about 540 yards (see Fig. 1). A perpendicular is erected at its centre, and a distance equal to $\frac{1}{15}$th of the exterior side is set off on it outwards. This point being joined to the extremities of the exterior side gives the direction of the faces of the cavaliers, the length of which is made $\frac{1}{6}$th of that of the exterior side. Upon the same perpendicular is set off, also outwards, a distance equal to $\frac{1}{3}$rd of the exterior side, giving the salient of the ravelin. With this point as a centre, an arc is described with a radius of 20 yards, to which tangents are drawn from the shoulder angles of the cavaliers; these lines mark the counterscarps of the ravelin, to which the escarps are drawn parallel, and the latter have a length of about 160 yards, short flanks being formed at their extremities. The flanks of the cavaliers are drawn at right angles, or nearly so, to the faces of the ravelin, they are made about 34 yards long, or sufficient for 4 or 5 pieces of ordnance. By joining the extremities of the flanks with the centre of the exterior side the curtain is traced; the counterscarp of the main ditch is parallel to the faces of the cavalier, and its prolongation gives the gorge of the ravelin.

In the centre of the curtain stands the defensive barrack, capable of accommodating 1,000 men, separated from the curtains by ditches 10 yards wide. The sides of the barrack have a length equal to the width of the ditch plus that of the terreplein of the curtain, and terminate in a circular part, which projects into the interior of the ravelin. The barrack thus serves—1st. as a redoubt for the ravelin; 2nd. as a kaponier to the main ditch; 3rd. as a general retrenchment or keep to the whole front. This circumstance constitutes an essential difference between this trace and those of the other German fortresses, in which separate buildings fulfil the different objects here accomplished by one only.

The covered way, which is of the usual dimensions, is provided with masonry guard-houses in the salient and re-entering places of arms; the ramps which lead to the covered way are placed on each side of the guard-houses, which thus protect them; the principal ditch is reached by passing through the ditches at the sides at the barrack, the level of which is very little lower than that of the interior of the fortress.

* For an account of the works at Ulm, on both sides of the river, see M. de Sellon's "Etudes sur la Fortification Permanente."—Ed.

The cavaliers and curtains are furnished with "chemins des rondes," at a level of 12 feet above the bottom of the ditch; the height of the escarp, in addition to this, is 16 feet; the counterscarp is 24 feet high; the relief of the curtains is 40 feet, and that of the cavaliers is 44 feet. The "chemin des rondes" is interrupted by the casemated batteries in the flanks, communication with which is kept up by posterns through the flanks. The "chemin des rondes" along the curtain is also reached from the ditches at the sides of the barrack. The gorge of the ravelin is closed by a wall joining that of the barrack; the rounded part of the latter has a small ditch flanked by three kaponiers, separating it from the interior of the ravelin. The entrance to this work is in the gorge-wall and is quite independent of that of the barrack.

The barrack is built with three stories, the first being only for musketry fire; the terreplein serves the purpose of a cavalier. The defensive corridor contains 20 casemates on each floor, not reckoning those in the towers in which the sides terminate.

The faces and the flanks of the ravelin are provided with "chemins des rondes," and their profile resembles that of the curtain. In the salient angle there is a battery for 5 mortars on the level of the "chemins des rondes," and another on the terreplein for 5 howitzers: these latter can only fire alternately on either side. The battery itself forms a traverse to the faces of the work.

In this trace the central works (which have been called ravelins) are independent, and the cavaliers and works joining them are the real curtains which enclose the spaces left between these central works. On account of their position and trace, the curtains cannot be enfiladed, and their fire, united with that of the upper tier in the barrack, is intended to retard the advance of the besieger from the very first period of the siege. A bastioned front, owing to its smaller extent, and notwithstanding its cross-fire, affords no greater amount of fire at the same period of the siege, and this moreover must cease as soon as the first batteries of the besieger have been brought into effective operation.

FRONTS OF THE CITADEL OF POSEN.—At the centre of the side of a polygon of about 430 yards in length, a perpendicular $\frac{1}{30}$th of its length is set off inwardly; by joining the extremities of the exterior side with that of the perpendicular, the direction of the curtain* is obtained, which has a slightly tenailled form; the faces of the (so called) bastions, each having a length equal to $\frac{1}{3}$rd of that of the exterior side, are parallel to and outside of the prolongations of the curtain, so that from the portion of the flank which projects beyond the curtain, the fire of two pieces in casemates may be brought to flank the latter; the remainder of the flank occupies the same space as the rampart of the curtain. A ditch, 8 yards broad, but closed by the escarp wall, separates the bastion from the adjoining curtain, and receives flank defence from the inner face of an orillon, which is built at the extremity of the face of each bastion. The main ditch is 25 yards wide, and is traced with its counterscarp parallel to the faces of the bastions; the salient of the ravelin projects about 150 yards beyond the counterscarp, its salient angle being 60°, so that this work, together with the redoubts of the places of the arms, covers nearly the whole curtain.

The bastions are closed at the gorge, in the centre of which is a masonry guard-house; an escarp gallery communicates with the battery in the orillon, which battery, it should be observed, is quite concealed from an enemy's view, as long as the central kaponier is not destroyed: the flanks do not fire on the ditch, but sweep the terrepleins of the adjacent curtains.

The central kaponier is made of a rectangular form, and has two tiers of fire, the lower for musketry, the upper for 5 pieces of ordnance.

* See the plans of this work given in the 3rd Vol. of the old series of the Professional Papers.—ED.

The ravelin, which is, from its position, exposed to ricochet fire, is constructed in the following manner—The halves of its faces next the salient have arches " en décharge," and the interior is full; the remainder has an independent scarp wall, and the interior is empty. There is a mortar battery in the salient, and in the centre of the gorge is a semi-circular battery which serves as a redoubt; this battery is separated from the ravelin by a narrow ditch; its revetted counterscarp contains a gallery connected with those in the gorge of the ravelin, and from the former the interior system of mines commences.

The ditch of the ravelin is closed by a casemate for two pieces, united with and forming part of the redoubt of the place of arms, which is casemated and has two stories. Thus the redoubt of the ravelin, the two casemates which close the ditch, and the redoubts of the places of arms, form one continuous line of works, similar to those proposed by Noizet, only casemated.

A draw-bridge leads from the second floor of the kaponier to the ravelin; and ramps, by the side of the redoubts, ascend to the re-entering places of arms.

In this trace, independent and isolated points, like the ravelins and bastions, are observable, so that, in considering the enceinte of the citadel, which is composed of two complete fronts and two half-fronts, it may be regarded as a series of enclosed works united by curtains.

It cannot be denied that the prevailing character of this trace is distinct from those already described. The communications are less numerous, and everything seems to indicate that a passive defence has been provided for; and this appears reasonable since this work is the last retrenchment of the fortress.

Grand Duchy of Baden.

Fronts of Fort Leopold and Fort B, at Rastadt.*—At the centre of an exterior side of about 440 yards, a perpendicular, from $\frac{1}{12}$ to $\frac{1}{20}$th of its length, is set off towards the exterior. Its extremity is joined to those of the exterior side, and the direction of the faces of the bastions is thus obtained. The length of these is equal to one-fourth of that of the exterior side. Fifteen yards are set off on the lines of defence from their intersection, to obtain points which, being joined, give the base of the kaponier. The flanks of this work, at right angles to the lines of defence, are long enough for 4 or 5 guns, and upon the line joining their outer extremities an equilateral triangle is constructed, the sides of which are the faces of the work. By producing these towards the interior, and drawing perpendiculars to them from the angles of the shoulder, the flanks of the bastions will be formed, and the terminations of the faces of the central part (called the cavalier) obtained. The counterscarp is parallel to the faces of the bastions and kaponier; the ditch of the latter is 18 yards, and the main ditch 23 yards wide. At the re-entering angle, formed by the junction of the bastion and cavalier, there is an enclosed space, on a level rather higher than the ditch; its outline is determined by the prolongation of the face of the bastion to its point of intersection with the production of the counterscarp of the kaponier, and by a straight line drawn from this point parallel to the flank of the bastion. It contains a battery for 3 or 4 pieces to flank the ditch of the kaponier. It was intended that this battery should have been casemated, but for economy's sake it has been built with piers only 6 feet long, supporting a gallery above, intended for musketry fire. The front thus consists of two demi-bastions, the flanking batteries, the cavalier, and the kaponier. The counterscarp has a gallery in it, and there are casemated redoubts two stories high in the re-entering places of arms. The ramps in the re-entering places of arms are placed to the right and left of the redoubts.

* A detailed plan of these works is given in the 1st number of the " Etudes sur la Fortification Permanente," by the Baron Maurice de Sellon.

The escarp wall of the bastion is 28 feet high, and is built with two rows of arches, the lower story being loopholed; there is also a "chemin des rondes" divided by traverses. A postern on the capital gives access to the escarp gallery and to the "chemin des rondes," and thence passing under the ditch, leads to the redoubt of the place of arms; two other posterns in the flanks lead to the flanking batteries, and from these two curved passages descend into the main ditch near the angle of the shoulder. The flanks of the bastions have no "chemin des rondes," but afford musketry fire from the upper gallery for defending the interior of the flanking batteries in case of their being assaulted.

The cavalier has a relief 5 feet greater than the bastions; like the flanks of the latter, it has no "chemin des rondes," but has loopholes in the upper escarp gallery. Upon the terreplein at the salient a space is prepared for a battery, which would be blinded in anticipation of a siege. The blindage would at the same time serve as a traverse to the faces of the cavalier. There is a postern on the capital which gives access to the escarp galleries and then leads to the kaponier.

The kaponier differs from those already described in having a mortar battery between the angles of the shoulder, on the level of the battery in the upper story of the flank; the latter, in addition to two tiers for artillery, is also provided with a banquette for musketry on the terreplein. The kaponier has no communication with the ditch, in accordance with the principle that no flanking work should serve as a passage for the troops intended to operate in its immediate vicinity.

Each front is provided with an advanced lunette on the capital of the cavalier; the lunette is closed by a gorge wall with a tower at its centre, and has a counterscarp gallery for flanking its ditches. In Fort Leopold, one of the fronts, in place of the lunette, has a ravelin or counterguard in front of the kaponier.

Bavaria.

Fronts of Germersheim.—In this polygonal trace*, the exterior side has been slightly tenailled, for the purpose of giving a better flank defence to the faces and flanks of the central kaponier. This work is connected with the escarp by two walls, and has direct communication with the interior by a postern, which also gives access to a loopholed escarp gallery.

At points about 120 yards from the flanked angle of the polygon, coupures are formed across the whole breadth of the terreplein and parapet; these coupures are well defended by traverses similar to those employed by Montalembert in his circular system. The bastion has a defensive barrack extending from one coupure to the other, so that it is completely isolated. In the flanked angles there are spaces reserved for batteries, which can be blinded, and serve as traverses.

The central kaponier is covered by a ravelin, and the ditch of the latter is flanked by casemated batteries which close its gorge, and are connected with the casemated redoubts in the re-entering places of arms. These batteries and redoubts have entrances from the ditch distinct from those of the places of arms and covered way; the ravelin and places of arms, with their redoubts, form a first defensive line which must be captured before the body of the place can be approached.

Front of a Bridge-head upon the Rhine opposite to Germersheim.—The work now to be considered is one in which the ditches are wet, and it shows how simply and naturally the polygonal system accommodates itself to this circumstance, and how, deriving from it all the advantages which must naturally accrue to the defence, it avoids the defects which stagnant water has been supposed to occasion, and which, according to Vauban, makes such positions the worst of all to defend.

* The plan of this is similar to that given at p. 194 of the 3rd Vol. of this Series, except that in the latter the counterscarp is not shown revetted, as it actually is.—Ed.

The front is a straight line or slightly tenailled, and is shown in Fig. 2:—The escarp is of earth, except at the salient angles, where two small revetted bastions are formed which are closed at the gorge, in the centre of which there is a masonry guard-house. The terreplein of the curtain is supported internally by a retaining wall, connected with the gorge walls of the bastions. The centre of the front is occupied by a large building, composed of three different parts, each intended for its own particular object. The most retired of these is a defensible barrack, the fire from which sweeps the terreplein of the curtain. The central part is the kaponier for the defence of the ditch, the faces of which are flanked by two small projections at its inner extremity; underneath there is an arched passage leading to the wet ditch, which is crossed by two bridges close to the work. (See Fig. 5).

The third and most advanced part of this building serves as a redoubt to the ravelin. Round the whole there is a dry ditch, on a higher level than that of the water, which leads to the terreplein of the ravelin, so that, by means of the bridge and this dry ditch, a continuous communication is kept up with the outworks without the use of rafts. The destruction of the bridges would be of little consequence, since from their small size, they could be soon replaced. The communications, then, would appear to be as easy as if the site were a dry one. The ditches of the ravelin are flanked by batteries which close their gorges, and which are united with the redoubts of the places of arms, forming with them one work; two loopholed walls unite these redoubts to that of the ravelin, and these three works thus constitute a continuous line of redoubts, communicating freely with each other and also with the interior of the fortress. By reference to the drawing it will be seen how the ravelin communicates with the places of arms, and also the mode of passing from these latter to the dry ditch of the central building without traversing the redoubts of the places of arms. (See Fig. 6).

Analysis of the German System compared with the Bastioned System, as regards its powers of Resisting Attack.

A comparison will now be made between the enceinte of Posen, on the left bank of the Wartha, and a bastioned fortress on a duodecagon, in which the faces of the bastions and the curtains are not exposed to ricochet fire. There will be no attempt in this comparison to arrive at so determinate and precise a result as to be enabled to fix the number of days' siege which one could resist longer than the other; for this purpose it would be necessary that the actual experience of war should have furnished data, which, as regards the German system, are entirely wanting. Zastrow, in his project of attack on Montalembert's system, supposes the construction of a counter-battery for destroying the central kaponier impossible, agreeing in the principle of the author of the system, that the construction of a battery, at a short distance from and under the fire of another ten times as powerful, is impossible. Zastrow thus terminates the attack without seeing any means of continuing it. As much cannot be said for the kaponier of the German system, since it does not possess such a great superiority of fire as to render the construction of counter-batteries impossible; but nevertheless the time occupied in their erection, and the sacrifices entailed thereby, would doubtless be very considerable; yet Maurice de Sellon, in his attack upon Rastadt, not taking into account these considerations, has no hesitation in affirming that these works would fall a certain number of days sooner than a bastioned fortress.

1. The fronts of the enceinte of Posen are 600 yards long, and the lines of defence 280 yards; the seven fronts cover the same extent of ground as twelve bastioned fronts, and there being 4 flanking batteries in each front of either system, the former would require only 28 batteries for the immediate security of the place, and the latter 48: supposing each battery to contain two pieces, there would thus be a saving of 40 pieces in favour of the German system.

2. Supposing the attack to be directed upon one ravelin, and the works having consequently to embrace the two collateral ones, the trenches would require to be much more extensive for the German fronts than for the bastioned ones, a circumstance of great importance which has not always been sufficiently considered. The fire of the fortress which opposes the establishment of the besieger's distant works preponderates in the German system*, and the guns on the upper terraces of the defensive barracks are very effective at this period. Up to the establishment of the third parallel the polygonal trace preserves a greater force of artillery not exposed to ricochet fire, and if its wide and well covered communications are taken into account, it seems fair to assume that up to this period of the defence the bastioned duodecagon is inferior. It may here be added that the works, which in the bastioned system have to be executed while the siege is progressing, are in the polygonal system existing beforehand, with the exception of a few blindages and palisades, for which the timbers are prepared, and can be fixed in a few hours.

3. Beyond the third parallel, the besieger's difficulties in carrying on the attack of a bastioned fortress increase extraordinarily, at least such is the theory; in fact he is supposed not to be able to advance a step without being exposed to reverse fire from the collateral ravelins, and to direct fire from the redoubts of the places of arms and the faces of the bastions. The fronts of Posen possess, though not to so great an extent, a similar advantage, but this does not exist in the other traces that have been described. None of these afford the formidable re-entering angles of the bastioned duodecagon, in arriving at which the besieger's hitherto uninterrupted progress would be stopped. In the former the crest of the glacis is so nearly parallel to the body of the place that the whole of the covered way can be crowned simultaneously, while in the bastioned system this must be limited to the salients of the ravelins. But how then, it may be asked, does the besieger overcome these difficulties and continue his saps upon the glacis? The answer is obvious, the artillery fire of the ravelins no longer exists, and in the exposed redoubts of the re-entering places of arms, overwhelmed with vertical fire, the pieces which still remain serviceable can hardly be manned; there is in fact no other fire left but that from the body of the place, which remains also in the polygonal trace. But further, the ricochet fire, which has destroyed that of the faces of the ravelin, has also in great part silenced the fire of its redoubt, the faces of which are parallel to them. In the German trace this redoubt is a barrack or casemated battery, the masonry of which is perfectly covered, and the redoubts of the places of arms, being also casemated, have been preserved uninjured. Thus in the one case the covering works and the redoubts have suffered almost equally, in the other all the interior defences have escaped injury.

4. The crowning of all parts of the covered way of the polygonal fortress may be effected simultaneously, but this operation is opposed by the fire of the casemated redoubts of the places of arms, by that of the central kaponier, by that of some guns at the extremities of the barracks specially arranged for firing on the salients of the collateral ravelins, and, in addition to this direct fire, there is the vertical fire from the

* Supposing that a front is traced according to each system, with the lines of defence of the works flanking the main ditch of the same length in each, the space available for artillery on the ramparts of the body of the place to bear upon the field of attack between two ravelins is, in the polygonal system, more than twice as long as it is in the bastioned system; and the fire from it is also much more direct, so that the whole of it may be concentrated upon any point in the 2nd parallel. It may also be observed that it will seldom happen that the exterior sides of a fortress can be arranged so as to form parts of a duodecagon, as supposed by the author, and that the faces of a polygonal fortress can always be traced so that the batteries intended to enfilade them must be placed so near to other parts of the body of the place as to render their construction very difficult.—Ed.

different mortar batteries. If at this critical period of the defence troops can be spared for a hand-to-hand encounter with the enemy, the possession of the crest of the glacis will not be secured without great loss to the besieger. The crowning of the glacis of the bastioned duodecagon, although not simultaneous, will probably cost him infinitely less.

5. The besieger having obtained possession of the crest of the glacis at the salient of the ravelin of the duodecagon, and of the corresponding work of the German front, would destroy the battery flanking the ditch of each in much the same manner; the descents into and passages of the ditches would also be identical, but the assaults of the ravelins in the two cases, and the formation of lodgments on them, would be very different operations. In the one case the assault would be opposed by a redoubt, the terreplein of which have been swept by ricochet fire; in the other, by a casemated redoubt, with different tiers of fire, prepared for this very moment, and by an interior system of countermines. The besieger would doubtless prefer postponing this assault, until he has destroyed the building which at the same time serves as a redoubt to the ravelin and kaponier to the body of the place.

6. To destroy this building he will proceed to establish a counter-battery on the crest of the glacis opposite the salient angle of the polygon. This operation is analogous to that undertaken for the destruction of the fire of the flank in the bastioned system. When the polygon has but few sides this flank will have preserved no fire, because the ricochet fire directed against the faces of the bastions, together with the shells with which the besieger will have inundated the terrepleins, will have destroyed its fire completely, even supposing it blinded. And although this might not have happened to so great an extent in the case of the bastioned duodecagon, there is every reason to suppose that the service of the artillery would be very slow and uncertain. The bomb-proof kaponier, on the contrary, would vigorously oppose the construction of the counter-battery and would contend with it until destroyed. Let the position of the besieger at this precise moment be attentively remarked, supposing that the ravelin is not taken and the redoubts of the re-entering places of arms are not destroyed.

7. It may be said that the prolongation of the defence by the use of the countermines would apply equally in each case, and this would be true were bastioned fortresses always provided with them; but as a matter of fact this is not the case, whereas they enter essentially into the construction of all the German fortresses.

An objection often raised against the German system, viz.: the excessive use of masonry works, must now be considered. "Masonry if seen will be destroyed," is an axiom of fortification; Montalembert, notwithstanding, dissented from it, and in his circular system left his masonry buildings uncovered, but so armed with artillery that upon every point of the besieger's works he could concentrate a number of guns considerably greater than it was at all likely could ever be brought to bear upon him; and he applied the same principle to his polygonal system. It has been easy to prove the fallacy of this opinion, and to show how readily an inferior artillery placed behind earth-works can successively destroy such buildings, the repair of which is impossible. The German engineers have not followed this maxim of his, and one of their principles is to cover their masonry from an enemy's distant fire. Thus the barrack in the Citadel of Posen is perfectly covered by the enceinte, and from this alone can it be seen. But limited as the besieger then would be in the extent of his position, and exposed as he would be at a short range to the fire of 60 or more pieces of artillery, circumstances would have been completely altered, and what would have been very easy of accomplishment from the 1st or 2nd parallel would now be immensely difficult. Somewhat different from the above example is the Citadel of Ehrenbreitstein at Coblentz.

Its northern front forms a defensive barrack of the bastioned form, the upper story of which is visible from the ground outside ; but this is a piece of table land which narrows as it recedes from the work, so that the front of the attack has not so great a length as the front of the barrack, besides which the soil is hard rock, so that the earth for the parapets of the parallels and batteries would have to be brought from a distance. Can it be said that this barrack would be destroyed solely because its walls are uncovered, and is it not evident that its destruction would cause immense sacrifices in men and time?

What has been remarked of the Citadel of Posen may be applied to that of Ulm and to the forts of Rastadt. But there are others of smaller magnitude, as the work at Posen, on the right bank of the river, the exterior forts at Cologne, &c., which are intended to accomplish objects analogous to those of the forts of Paris. The fronts of these latter are bastioned and about 330 yards long, they have no outworks, and no interior redoubts; the besieger would rapidly reach their counterscarp, and having opened a breach, would find nothing to oppose his assault. In the German fronts, on the contrary, it has been shown what a number of successive operations the besieger would have to undertake, and what great means of resistance the besieged possess.

In the analysis which has just been made, it has been supposed that the defensive barracks and other batteries have been preserved uninjured up to the last period of the siege, from the simple fact that their masonry, being covered by earthen works of the same relief, is exposed to no direct fire from the ground outside. But the Woolwich experiments* have proved that this means of cover is insufficient, and that a wall so protected may be destroyed by a distant pitching fire from heavy pieces. This fact being established, the attack must necessarily be modified, and the consequences before arrived at will be considerably affected ; indeed no fixed or definite conclusion can be come to while there is any doubt as to the greater or less amount of injury to which each work, according to its position, would be exposed.

A doubt has been expressed on a former page as to whether the kind of fire at present under consideration is efficacious only against detached walls, and whether it cannot be rendered equally so against ordinary revetments; it is now asserted that the destruction of the detached wall in the Woolwich experiments by no means proves the certainty of that of the wall of a casemated building, strengthened as it is by piers and arches.

Granting, however, a certain destructive power to this pitching fire, provided it can be directed perpendicularly, or nearly so, to its object, it will now be considered how far the result before arrived at must be modified, still referring to the fronts of Posen.

1. The redoubts and block-houses in the salient and re-entering places of arms will suffer very little, on account of their close proximity to the glacis which covers them.

2. The low flanking batteries sweeping the ditch of the ravelin will probably be destroyed. The rounded parts of the barrack serving as a redoubt to the ravelin will also have suffered considerably, but there is no reason why the garrison should abandon the remainder of the building which no shot can have injured.

3. In possession of the ravelin, the besieger will next find it necessary to destroy the batteries of the kaponier, for which purpose he must establish himself in front of it and directly under its fire, as has been before remarked. In the town fronts of Posen there is a special circumstance which may tend to throw some doubt upon what has been just stated, and that is the fact of the redoubt of the ravelin and the kaponier for the defence of the ditch forming only one building. But with regard to the Citadel of Posen there can be no doubt that the destruction of the redoubt of the ravelin will not be necessarily followed by that of the defences of the enceinte.

* See also result of experiment on a pitching fire against a casemated building as recorded in the Professional Papers, Vol. VII, New Series, pp. 42 and 43.—Translator.

Supposing now that the besieger has obtained possession of the enceinte of the citadel he will have to carry on his attack against its keep. For this purpose he must either establish batteries on the terreplein (and of this the immense difficulties have been already pointed out) or else in some more retired position (and consequently more distant from the keep) for pitching fire. The distance of these latter could hardly be less than 600 yards, which is one half more than that in the Woolwich experiments; to a considerable height the barrack is covered by a glacis, and it cannot be imagined that shot could be fired with sufficient accuracy as to pass over the exterior works, just graze the crest of this glacis and strike the wall at a lower level. It will thus be seen that there are no grounds for assuming that barracks like the one in question can be readily destroyed.

The larger cost of works constructed according to the German system, as compared with the bastioned, being often urged as a reason against the employment of the former, it seems desirable to investigate the actual facts connected with this part of the subject. According to Merkes, the cost, per front, of an octagonal fortress is as follows:—

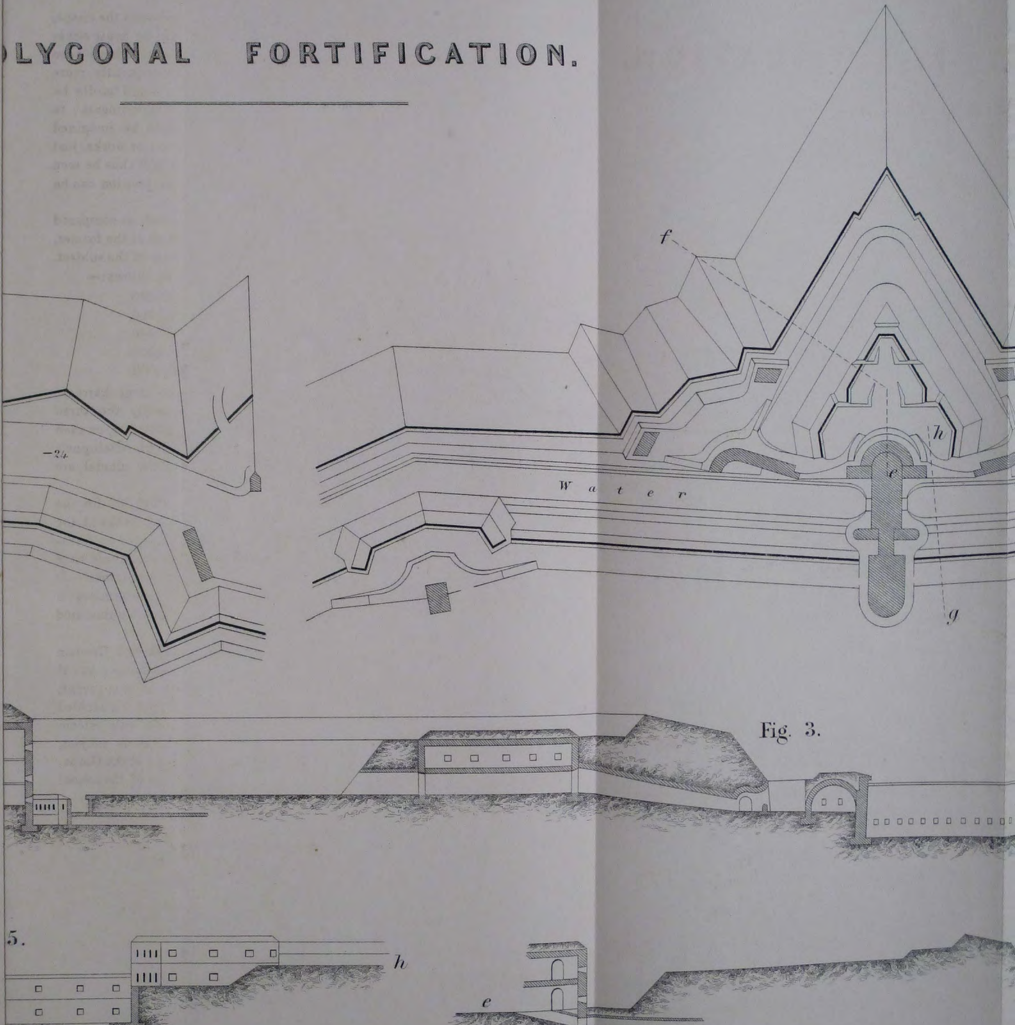
First system of Vauban	£47,000
Third „ „	62,000
System of Cormontaingne	67,000
" Coehorn	40,000
" Bousmard	65,000

The Citadel of Posen cost altogether £356,000, of which sum the large barrack, powder magazines, and gorge tower consumed £116,000; consequently the three fronts and the two branches (connecting the fronts and keep) cost £240,000, or each front may be assumed to have cost £60,000, less even than a front on Cormontaingne's system; besides which it must be borne in mind that the fronts of the citadel are about 60 yards longer than those of Cormontaingne.

The total cost of the same fortress was £1,140,000; deducting £356,000 for the citadel, there remains £784,000 for the enceintes on the right and left banks of the Wartha, and for the two bridge-heads. If the same space had been enclosed by fronts on Cormontaingne's system, twelve would have been required, and the cost would have been £804,000, nor does this sum include the expense of barracks and magazines. It is also necessary to observe that the cost of the construction of countermines is included in that of the German works, which is not the case in that of those enumerated in Merkes's table.

In the foregoing remarks upon the comparative merits of the French and German systems the author has endeavoured to preserve the most strict impartiality; and it was his original intention not to have allowed his own views to have been apparent. This latter object however has not been attained, and in almost every page his decided convictions in favour of the German system will be observable. He will esteem himself happy if this memoir, in conjunction with others upon the same subject, contributes in the least degree to arouse a spirit of enquiry among officers of the Corps, and thus to fix, as far as possible, what is to be the system of fortification of the school of Spanish Engineers.

…OLYGONAL FORTIFICATION.



PAPER XXIII.

Description of the Engineer Field Equipment of the Turkish Contingent.

By MAJOR STOKES, Royal Engineers.

In the month of April, 1855, the Minister of State for War, Lord Panmure, directed Major Stokes, of the Royal Engineers, to organize an Engineer force for the Turkish Contingent, and to prepare a suitable Engineer equipment for a force of 20,000 men, which it was intended to make complete in every respect as a separate Corps d'armée, composed of two divisions of Infantry, one division of Cavalry, and one of Artillery.

The object of this Paper is to give a short account of the above-mentioned equipment, that it may serve as a basis for further improvements in forming a model for future Engineer field trains, when it may again become necessary for an English army to take the field.

The points which it is proposed to explain are :—

1st. The composition of the Engineer force; distribution and general description of the train.

2nd. The equipment of tools, &c.; their assortment and arrangement on the carriages; differences of construction of the carriages.

3rd. The pontoon and boat equipment.

4th. The scientific apparatus.

Appendix. The cost of the carriages, pontoons, tools, stores, &c., &c.

1. The Composition of the Engineer Force, Distribution and General Description of the Train.

The Engineer force was organized in five companies, thus distributed :—

No. 1. Reserve at head-quarters.
„ 2. 1st division of Infantry.
„ 3. 2nd „ „
„ 4. 1st „ „
„ 5. 2nd „ „

It was originally intended that these companies should be composed of a nucleus of English artificers, and that the bulk of them should be Turkish artificers drawn from the Infantry regiments. This intention could not be carried out, on account of the absence of artificers in sufficient numbers, and an augmentation of the English portion of the Corps was sanctioned; but the conclusion of peace rendered the raising of it unnecessary.

The Train, which was to be driven by a Corps of Drivers raised in Wallachia, officered by Wallach gentlemen, and organized as two troops under an English commandant, may be divided into five parts :—

1. The carriages for intrenching tools.
2. The carriages for artificers' tools and stores.

3. The pontoon carriages.
4. The light train of pack animals.
5. The carriages for scientific apparatus.

1. The carriages for intrenching tools consisted of—
    24 wagons (C).
    16 carts (I).
2. The carriages for artificers' tools and stores:—
    6 wagons for tools (A).
    6 carts for ditto (G).
    6 wagons for stores (B).
    12 carts for ditto (H).
3. The pontoon carriages—
    32 wagons with pontoons and superstructure (D).
4. The light train of pack-animals consisted of 40 horses with pack-saddles and leather panniers, in which light tools and stores could be carried.
5. The carriages for scientific apparatus—
    1 electric telegraph wagon (E).
    1 photographic wagon (F).

DISTRIBUTION OF CARRIAGES.

Company.	Wagons.						Carts.			Pack Saddles.	Remarks.
	Flat. A	Store. B	Intrenching Tools. C	Pontoon. D	Electric Telegraph. E	Photograph. F	Flat. G	Store. H	Intrenching Tools. I		
1.	2	2	-	-	1	1	2	4	-	16	
2.	1	1	12	-	-	-	1	2	8	6	
3.	1	1	12	-	-	-	1	2	8	6	
4.	1	1	-	16	-	-	1	2	-	6	
5.	1	1	-	16	-	-	1	2	-	6	

The 1st company, being intended to act as a reserve at Head-quarters, received a larger supply of artificers' tools and stores, and had the scientific apparatus and the India rubber boats attached to it.

The bodies of these vehicles varied according to the purposes for which they were intended; but the axletrees of the whole were the same, and the wheels were only of two kinds, allotted according to the following table. The only exception to the uniformity of the wheels was the photographic wagon, of which the wheels corresponded with those of the hospital train.

The table below shows that the hind wheels of the pontoon wagons correspond with the cart wheels, and the fore wheels with the wagon wheels of the Train.

Height of Wheel.	Pontoon wagon.		Wagon for Intrenching and Artificers' Tools.	Carts.	Electric Telegraph Wagon.
	Fore.	Hind.			
4′ 2″	2	-	4	-	4
4′ 6″	-	2	-	2	-

All the tires of the wheels are made according to the patent of Messrs. Holmes, of Derby, of which the peculiarity is a projecting rib on its whole circumference, whereby, on a hard road, the friction is very much diminished; further trials are needed to prove whether any advantage is gained on soft ground.

The wagons A, B, C, E were all constructed on the Jacob's lock principle, having four wheels of equal size, by which an advantage of draught was obtained; but the tendency of this wagon is to throw too much of the weight on the hind wheels: the precaution of loading well forward must therefore be always taken, otherwise in ascending a hill the body is liable to tilt backwards, and separate from the fore axle. There is also a difficulty in locking the hind wheel whilst descending a hill. It is at present only managed by throwing a great strain on the body of the carriage: an improvement upon this is much needed. The fore-axle frame being moveable the drag chain cannot be attached to it. It has therefore been made fast to the fore and aft side bar of the carriage, which its action has a direct tendency to fracture.

Each carriage is fitted with an upright in front and rear, connected by a top rail, over which is stretched a tarpaulin, provided with straps and buckles for connecting it with the body of the carriage.

The bodies of all the carts and wagons, except the pontoon wagons, are mounted on India rubber springs, which have been found to answer very well, retaining their elasticity under very heavy loads, in frost and in heat, and returning to their proper shape on removal of the load.

The wagons are fitted with poles and swingle trees, the carts with moveable shafts and a sliding splinter bar of iron for a second horse. Each carriage should be provided with a pickaxe, shovel, felling axe, and hatchet, for the removal of obstacles on the march.

2. The Equipment of Tools, &c.; their Assortment and Arrangement on the Carriages; Differences of Construction of the Carriages.

The equipment of tools, &c., may be divided into three branches:—

I. The intrenching tools.
II. The artificers' ditto.
III. Miscellaneous stores.

I. Intrenching Tools.—These consisted of:—

5,000 pickaxes.
5,000 spades and shovels.
500 felling axes.
500 hand axes.

These numbers were fixed on the assumption that for throwing up any series of field works to cover the front of an army, means should exist for placing intrenching tools in the hands of one-third of the strength, and a good supply should be at hand to make good breakage and loss.

In the Turkish army the soldier does not work with both pick and shovel: one carries a pick and another a shovel. The Contingent numbered 16,000 Infantry. The above numbers therefore amply sufficed for their wants.

The tools were supplied by Messrs. Lindon and Co., of Birmingham, and were of the best description; their quality was well tested, and their excellence proved in the construction of extensive lines at Kertch in the winter of 1855-6, where the Turks cut through a considerable amount of rocky soil with the pick alone. The pick-heads being of cast steel, and consequently requiring care in transport, the wagons (C) and carts (I) destined to carry the intrenching tools, were constructed so as to keep the pick-heads separate from one another. Each carriage had two partitions lengthwise. Two rows of staples were fixed at about six inches from the top and bottom of each side and partition, about four inches apart; through each row of staples was passed a leather strap which could be relaxed and tightened at pleasure. These straps formed loops in which were secured the pick-heads; the helves, shovels, spades, and axes were packed between the rows of pick-heads. The wagons and carts were loaded as follows.

Each wagon was to carry 2,053 lbs., or rather more than 18 cwt., viz.:—

		lbs.
125 pickaxes	at 7 lbs.	875
34 do.	at $8\frac{1}{2}$ „	289
138 shovels	at $4\frac{1}{2}$ „	621
16 spades	at $5\frac{1}{4}$ „	84
15 felling axes.	at $5\frac{3}{4}$ „	$86\frac{1}{4}$
15 hand axes	at 2 „	30
34 spare helves	at 2 „	68
		lbs. $2,053\frac{1}{4}$

Each cart was to carry 985 lbs., or nearly 9 cwt., viz.:—

		lbs.
62 pickaxes	at 7 lbs.	434
11 do.	at $8\frac{1}{2}$ „	$93\frac{1}{2}$
74 shovels	at $4\frac{1}{2}$ „	333
7 spades	at $5\frac{1}{2}$ „	$38\frac{1}{2}$
8 felling axes.	at $5\frac{3}{4}$ „	46
8 hand axes	at 2 „	16
12 spare helves	at 2 „	24
		lbs. 985

It was intended that the carts should always move with the divisions of Infantry, and the wagons with the heavy train of the army, to be brought to the front when larger numbers of tools were required.

II.—Artificers' Tools.—A selection of the trades most required by the wants of an army having been made, the tools necessary for their efficiency were assorted (as shown in Appendix I) and packed in chests, which were allotted as follows:—

Trade.	Chests.	Company				
		1	2	3	4	5
Carpenter's	22	6	6	6	2	2
Smith's and tinman's	7	1	1	1	2	2
Sawyer's	5	1	1	1	1	1
Mason's and bricklayer's . .	10	2	2	2	2	2
Miner's	6	2	2	2	-	..
Cooper's	5	1	1	1	1	1
Collar maker's and shoemaker's	7	1	1	1	2	2
Well sinker's	3	1	1	1	-	.
Armourer's	5	1	1	1	1	1
Farrier's	11	3	2	2	2	2

Each chest contained a complete assortment in itself, and was so arranged that any tool could be seen at once, that no delay might arise when men arrived at their work from tools not being at hand. The only exception to this rule was in the mason's chest, where the weight of the tools compelled a division.

Considerable credit is due to the Messrs. Rabone, of Birmingham, who supplied these tools, for the trouble they took to hit upon the best mode of packing them.

It has been found in the hutting operations of the winter 1855-6, that for rough workmen the saws were of rather too good quality, not being strong enough for the uses to which an unskilled workman would apply them. It is recommended that for hutting purposes an additional supply of a coarser tool should be provided.

A portion only of the chests were intended to be always carried with the troops, the remainder were to be left as a reserve from which to supply casualties. The carriages for their conveyance were flat, without sides, the bottom consisting only of strong battens. The chests were all made with rope handles, by which they were to be lashed down to the battens and thus kept from shifting.

The chests were as far as possible so arranged on the carriages* that each should be complete with all kinds of tools.

III.—Miscellaneous Stores, &c.—The stores and tools that come under this head do not admit of a particular description: a list of them will be found in the Appendix No. I, but a few of them may be mentioned—Nails and spikes were packed in small iron cylinders holding each 50 lbs. weight. The grindstones were packed in

* N.B.—Captain Allan, Adjutant of the Turkish Contingent Engineers, was instructed to make the most convenient arrangement of the loads before giving over the Train in England. The result of his endeavours has not been communicated to the writer of this Paper.

boxes of which the upper half could be unshipped: the spindle of the stone rested and turned in two grooves in the lower half, and this had two projecting feet by which it could be screwed down to a fixed log of wood at any place; it was also water-tight, and thus the stone could be kept wet whilst grinding.

The lifting jacks were of two kinds—one, the ordinary rack and pinion, with crank-handles, the other, an Archimedes' screw worked by a short lever. The latter is very powerful, but has an inconvenience in the difficulty of working the lever, that frequently occurs.

The sapping tools were all made from the Chatham patterns.

The Ordnance wheelbarrow was adopted on account of its portability; but wooden wheels with iron tires were substituted for the old cast-iron wheel.

Spare wheels and axle arms for all the carriages were provided on a liberal scale.

The carriages for the conveyance of stores were the same as those for intrenching tools, with the exception of the partitions and arrangement for the pick-heads.

An addition to the stores, tools, carriages, &c., was contemplated if the Corps had been augmented as intended.

3. The Pontoon and Boat Equipment.

I. The Pontoon Train consisted of two bridges of Blanshard's large pontoons, each bridge being composed of 16 rafts, or 32 pontoons.

The drawings used in Woolwich Arsenal were followed in their construction by Messrs. Deane and Dray, of London Bridge, the only deviations being in the rings at the extremities, which were made rotatory, and in the handles, round which gun-metal cylinders were introduced. These cylinders have play enough to turn easily round the handles, so that men carrying the pontoons by hand are allowed greater freedom of the wrist. The pontoons are made of tin of superior quality and strength to that used in the Arsenal, and the internal wheels which strengthen the cylinders are of stouter metal.

The superstructure of the rafts is exactly like that shewn in the Aide-Mémoire. The carriages differ in some material points. The bolsters rest on strong steel springs, which lighten the draught, the axle-trees being kept in their position by iron stays. The wheels are made far lighter than in the old carriage, and somewhat higher, that they may be of the same pattern as the rest of the Engineer train; the axletree was also much lightened by combining wood and iron, and the axletree arms are connected by an iron bar bolted through to the wood-work.

It appears then that the pontoon carriages of this Train have been made much lighter than formerly. Experience of them is required to ascertain whether the other extreme has been entered: the old carriage was unquestionably too heavy; the new ones may have been made too light, from the desire to use the same wheels for them as for the rest of the train. The springs have the disadvantage of throwing the centre of gravity of the load higher, but this is counterbalanced by the pontoons being now sufficiently high to clear the horses and not incommode the drivers.

It is earnestly recommended that the new pontoon train should undergo the test of long marches over bad roads to ascertain the advantages or defects of these changes.

The bodies of the carriages were made by Messrs. Dray and Co.; the axletree arms and wheels were supplied by Messrs Crosskill, who built the rest of the carriages, to ensure uniformity in the whole train. Messrs. Dray and Co. also supplied the superstructure of the rafts.

II. The Boat Equipment consists of ten India-rubber boats.

Each boat consists of a waterproof floor stiffened by light planking, and surrounded by an inflated cylinder in eight compartments. The interior space within the cylinder is 10 feet long by 2 feet 6 inches wide and 1 foot 3 inches high. The floor, of light planking, is in three parts, stiffened by battens of the length of the boat traversing the joints at right angles, and passing under strong straps. The thole pins for the oars are inserted into a bar which is strapped on to the top of the cylinder on each side, and the bar is in two parts connected by a hinge. The light oars or sculls are in two parts, one being provided with a socket into which the other fits and is secured by a screw of galvanized iron. The cylinder is inflated by bellows, which screw into nozzles similar to those in general use. These nozzles are placed, for security from wet, &c., under a flap that projects all round on the inner side of the cylinder, on which seats are supported. Each boat holds 14 or 15 men sitting on the cylinder, two of them rowing with a pair of sculls each. Twelve men of the fourteen, sitting or standing on one side, could not upset the boat when tried at Tilbury. When not inflated it folds into a package about four feet square and two thick; with its covering it weighs 178 lbs. It can be carried on a mule's back at a pinch, but a cart is recommended as preferable, on account of the injury that must arise from the chafing caused by a mule's motion. The flooring, oars, bellows, &c., &c., pack into a canvass bag, and can be carried in the same way as the boat. Two men of the Turkish Contingent Engineers were fully instructed at the Manchester manufactory of Messrs. Macintosh and Co. in all the working of the trade; and each pair of boats are abundantly provided with materials for their repair.

J. STOKES, Captain R.E. and Major.

The following remarks on the scientific apparatus were prepared by Lieutenant Beaumont, Royal Engineers:—

I. Scientific Instruments.

On the scientific instruments no remarks are necessary, their uses are well known, and the ends they were to attain are self-evident.

II. The Photographic Apparatus.

Photography has not long been brought to such perfection as to enable it to be applied to military purposes. By its means general positions may be more correctly taken than it would be possible, by other means, to do. All works in progress can be accurately delineated, and the comparison of such delineations, taken at intervals, would show the periodical progress of the works.

The apparatus was very complete and answered the ends expected of it; the chemicals were found to be excellent in quality, and for the time calculated, sufficient in quantity; of the gross quantity of chemicals taken a year's fair consumption required about one-third.

The wagon itself appears, from the report of the photographic clerks, to have been faulty in one or two respects: there was no provision made for ventilation, and the heat attracted by the tarpauling covering was such as to render it nearly impossible to work inside the wagon during hot weather; * the light also was not effectually excluded, whilst the sink at the bottom of the vehicle was too small.

* I would suggest yellow as more suitable than lead colour to paint the canvass of such wagons for the future.—F. B.

III. The Electric Telegraph Wagon.

As with photography, so has the electric telegraph been but recently called to assist military operations, and consequently practice will doubtless point out many improvements and alterations to be effected in its arrangement and use for the future. It is to be regretted that no opportunity was afforded of obtaining such practical information, by testing the apparatus as provided, under the direction of Major Stokes, R.E., for the Turkish Contingent Train.

The wagon contained, as the list shows, all the apparatus necessary for establishing and working a telegraph to an extent of ten miles, with two terminal and two intermediate stations; also Voltaic batteries, and complete arrangements for firing charges of powder by electricity.

Though an electric telegraph may accompany an army in the field, it was never supposed that it could be used whilst that army was in motion, its object being to afford instantaneous internal communication between the various Corps d'armée of such a force, when in any position it was likely to occupy for a certain time. That such an end is desirable there can be no doubt, but whether the form of electric telegraph now alluded to, is the one best calculated for meeting such end, is a question still to be solved.

It only remains, now, to state the reasons for selecting the particular form of apparatus now in question. Single needle instruments were preferred, on account of their simplicity and facility of repair when broken, there being, in fact, nothing in their construction that could get out of order, with the exception of the coils and needles, of which an extra supply was taken. The rate of transmission with this method is slow, but this is evidently of little consequence in the present case.*

The main body of the wire taken was No. 16 galvanized charcoal iron wire, uncovered, which necessitates the use of insulators and the support of the wire on posts, or otherwise. At first sight, the covered gutta percha wire seems more suitable, as it requires but laying in the ground: on considering the facts of the case, however, this system has many disadvantages:—1st. It is about twelve times as expensive as iron wire, as shown in the list of prices; 2nd. After use for a certain time the perfectly insulating powers of the gutta percha are liable to deterioration, while the exact point or points where a loss of electricity takes place are difficult to determine; 3rd. It is troublesome to remove, being liable to get deranged in taking it up from the ground; 4th. The bulk and weight are so great that it would have rendered a second carriage necessary to convey the wire alone, had covered wire been taken. With the uncovered wire we have the advantages of cheapness, good insulation, light weight, and little bulk, whilst it may be easily removed, and suffers nothing thereby. Against these must be set the disadvantage of its requiring support; but when it is allowed, as at first premised, that the telegraph is only to be used when the army is in position for a certain time, this objection can never be weighed against the more serious ones attending the use of the covered wire, as there are hardly any positions in which sufficient wood might not be obtained to support the wire, while, in passing through a camp, the tops of the tent poles might be made available; in fact there must, doubtless, always be means, which an engineer might find, of getting over such a difficulty. For these considerations it was considered advisable to provide the main quantity of the wire uncovered, taking out a proportion of the covered to meet particular exigencies.

* The Morse instruments are in every respect preferable when anything like permanent establishments are intended.—F. B.

No. 16 wire is large enough for any moderate length of telegraph; should, however, the electricity be required to pass through a greater distance, increase of battery power will force it to do so.

Of the remaining parts of the telegraph apparatus, suffice it to say that the batteries were of the kind known as sand batteries, with copper and zinc plates, fitted in gutta percha cases, of the simplest possible description, and that all tools and apparatus necessary both for the laying down of the line of telegraph, and the management of the electricity, were provided and contained in the wagon.

IV. Voltaic Apparatus.

The Voltaic apparatus, for firing mines, consisted of four Grove's batteries of six cells, each fitted in strong oak cases, the zinc plates were bent in the form of a U, in order to present a surface of zinc to each side of the platinum, and the connections were arranged, as far as possible, with a view to simplicity, and, at the same time, to allow of the plates being easily removed and replaced. The method of firing was by means of a heated platinum wire, in the usual manner, and needs no description.

Contents of Electric Telegraph Wagon, by Compartments.

First Box (over fore axle).

2lbs. of sheet gutta percha
1 oil stone
1 naptha lamp
500 5-in. screws
4 hammers
12 screw drivers
8 hand files
4 soldering irons
6 gimlets
4 magnets
8 pairs of pliers
2 bill-hooks
4 axes
4 mattocks
4 spades
2 saws
1 mallet
2 bradawls
4 chisels
1 spanner
2 hand vices
2 steel chisels
2 rules
1 tool basket
1 box with 60 spare battery plates
2 detectors
6 glass cells
1 box of platina wire

Second Box.

8 batteries
4 acid pourers
1 quart of naptha
2 lbs. of rosin
2 gallons of sulphuric acid
1 gallon of nitric acid
10 miles of No. 16 wire
Sand and shackles
1 pint of sweet oil
Spindles for Barrow.

Third Box.

4 Grove's batteries
4 instruments and cases
3 spare coils and boxes
2 upright springs
2 bridge pieces and screws
4 terminals
2 axles and needles

Fourth Box.

2 miles of gutta percha wire
2 drums for wire
Quantity of shackles
1 cwt. 20 lbs. of marine glue
1 Ladder

Contents and Prices of the Chests of Tools and other Implements, supplied by Rabone, Brothers, & Co., Birmingham, for the Turkish Contingent Engineers.*

Seven Sets Smiths' Tools,

Each containing:

	s.	d.	£	s.	d.
1 set taps and dies at	5	6	0	5	6
1 stock and die .	47	6	2	7	6
2 rymers .	0	8	0	1	4
1 countersink .	0	8	0	0	8
2 hand hammers 2s. &	2	7	0	4	7
1 riveting ditto .	1	2	0	1	2
1 sledge ditto .	4	10	0	4	10
2 cold chisels .	2	6	0	5	0
2 cutting ditto .	2	3	0	4	6
1 vice, 3 ft. 6 in. long and pointed .	17	6	0	17	6
1 pair small pliers .	1	7	0	1	7
6 pair tongs .			0	9	0
1 flat file, handled, 12in.			0	1	0½
1 ditto, 14 in. .			0	1	5
1 half-round, do., 12in.			0	1	2
1 iron brace .			0	3	6
			5	10	3½
Case for ditto.			1	19	0
			7	9	3½

Seven Sets Tinman's Tools,

Each containing:

	s.	d.	£	s.	d.
1 pair snips . at	3	0	0	3	0
1 pair shears .			0	16	3
1 soldering iron .			0	2	6
1 ditto, in addition .			0	7	9
20 lbs. solder .	1	1	1	1	8
Melting do. into small bars .			0	0	10
1 tinman's anvil .			0	15	0
2 ditto hammers .	1	4	0	2	8
2 taking-up tools .			0	9	6
1 tinman's beak iron .			0	18	0
1 crease iron .			0	12	6
2 hollowing hammers			0	8	9
1 square-face ditto .			0	2	3
2 tinman's mallets, large and small, at 1s. 4d. & 1s. 2d.			0	2	6
1 ditto, hatchet stake, 18 in. high, 18 in. wide, and 3 in. deep			0	10	0
1 riveting hammer .			0	2	4
1 pair round-nose pliers			0	1	4
1 set of 3 hollow punches			0	9	3
1 set of 2 pincers, to take rivets			0	1	0
1 set of 2 cold chisels			0	1	0
1 ditto for rivets .			0	1	6
1 set of (2lb. each) rivets			0	1	9
1 lb. salamonica .			0	0	8
½ lb. borax . .			0	0	8
1 lb. spelter . .			0	1	2
			7	13	10

Total.

	£	s.	d.
Smiths' tools, 1 set .	£7	9	3½
Tinman's do. . .	7	13	10
	15	3	1½

Weight of each case.	cwt.	qr.	lbs.
Tools	1	2	26
Chest	0	2	16
	2	1	14

Seven Sets Collar Makers' and Shoemakers' Tools,

Each containing:

	s.	d.	£	s.	d.
1 half-round knife at	1	5	0	1	5
1 gross saddlers' awls			0	5	6
1 doz. handles for do.			0	1	0
1 gross collar needles			0	15	0
1 pair clamps . .			0	5	6
2 hand leathers . .	0	7	0	1	2

* It must not be forgotten that the prices of these articles are higher than those which would be paid in time of peace.—Ed.

	s.	d.	£	s.	d.
1 saddler's hammer .			0	1	2
6 lbs. sewing hemp .	1	3	0	7	6
2 lbs. resin & 2 lbs. pitch			0	1	2
1 gross shoemakers' awls			0	4	3
1 dozen handles for ditto			0	1	0
4 shoe knives . .			0	0	11
2 ditto hammers .	0	8	0	1	4
6 pairs lasts, 5 to 10 .	1	3	0	7	6
1 pair saddlers' pincers			0	1	9
1 collar iron . .			0	2	7
1 hand crease . .			0	0	3
1 screw . . .			0	0	9
1 hand knife . .			0	0	9
1 packet harness needles			0	9	0
1 ditto pointed . .			0	5	0
1 dozen pack ditto .			0	0	6
6 thimbles . .			0	0	4
1 collar mallet . .			0	3	0
1 set punches, oval 10s. round 8s. . .			0	18	0
1 pair scissors . .			0	1	4½
12 lbs. 2-thread best collar makers' raw twine . .	1	11	1	3	0
2 lbs. bees' wax . .	1	9	0	3	6
1 pair punch pliers with spare bits .			0	2	0
1 box of 250 copper rivets ½ to 1 in. .			0	18	0
1 ditto flat-head tinned tacks			0	1	9
1 saddler's stone .			0	2	6
1 best large round knife			0	2	2
1 seat iron . .			0	0	10
1 pair wing compasses			0	1	1
2 palm-irons, bent & straight			0	1	5
1 pair strong pliers .			0	0	10
1 do. cutting nippers .			0	0	10
1 do. nail pincers .			0	0	9
1 do. compasses .			0	0	5
1 riveting hammer .			0	0	10
Case for ditto .			2	1	0
Value per set .			9	18	7½

Weight of each chest.	cwt.	qr.	lb.
Tools . . .	0	3	3
Chest . . .	0	2	19
	1	1	22

TWENTY-TWO SETS CARPENTERS' TOOLS,

Each containing:

	s.	d.	£	s.	d.
5 hand-saws . at	3	1	0	15	5
3 felling axes . .	3	6	0	10	6
5 carpenters' axes .	3	9	0	18	9
6 extra helves, for felling and carpenters' axes	0	10	0	5	0
3 claw hammers .	1	6	0	4	6
2 ditto . . .			0	3	6
1 riveting . . .			0	1	3
1 pair pincers . .			0	1	2
5 adzes . . .	3	2	0	15	10
Set of 12 spike gimblets			0	7	0
Set of 36 nail ditto .			0	8	0
Set of firmer chisels .			0	8	6
Set socket ditto .			0	12	6
1 cold chisel . .			0	1	4
Set of mortice chisels.			0	15	9
5 rules . . .	1	7	0	7	11
Set screw augurs .			1	7	0
1 brace, rotatory handle, and bits . .			0	17	0
Fitting on leather .			0	4	9
2 pair compasses 1s. 4d. &	1	10	0	3	2
2 carpenter's squares, with steel blades, 6 in. and 12 in. .			0	3	5
2 mallets . .			0	2	11
1 jack plane . .			0	3	6
6 spare irons for ditto	1	6	0	9	0
1 trying plane . .			0	4	6
1 smoothing ditto .			0	2	9
1 rabbetting ditto .			0	1	10
6 spare irons each, trying, 1s. 9d., smoothing, 1s. 6d., rabbetting, 6d.			1	2	6
2 saw sets 11d. and	1	1	0	2	0
50 hand-saw files, per doz.	2	10	0	11	10
3 handles for ditto .			0	0	3¼
50 pit-saw files, per doz.	3	9	0	15	7½
3 handles for ditto .			0	0	3¼
1 spoke-shave .			0	0	7¾
1 drawing knife .			0	2	3
1 oil stone . .			0	1	10
2 screw drivers, 7¼d. and	1	6¼	0	2	1½
1 picking gouge .			0	1	5
1 firmer ditto . .			0	0	11

		£	s.	d.
1 ploughshare & irons		0	14	0
3 sets spare irons for do.	3s. 0d.	0	9	0
1 chalk line and reel .		0	0	4
1 bevil . . .		0	1	8
1 lb. chalk in tin box .		0	0	4½
50 iron spikes . .		0	1	4½
50 nails each 2, 2½, 3, & 4 in.		0	1	0
Half gallon sweet oil .		0	3	6
3 gross screws 2, 2½ & 3½ in.		0	10	4
1 ditto, 1¼ in. . .		0	2	10
1 lb. Flemish tacks .		0	0	8
1 rasp, handled .		0	1	2
1 tenor saw . .		0	4	4
1 screw wrench . .		0	8	0
1 set bradawls, 3 each, 6 sizes		0	2	6
1 punch . .		0	0	1¾
1 compass saw . .		0	0	11
22 marking gauges .		0	8	3
		17	9	2
Chest for ditto.		3	5	0
		20	14	2

Weight of each chest.	cwt.	qr.	lb.
Tools . . .	2	1	25
Chest . . .	1	0	11
	3	2	8

Pit and Cross-cut Saws.

Two sets, each containing:

			£	s.	d.
3 pit saws, 7ft., complete			2	14	0
3 cross-cut saws, 5 & 6ft.			1	4	3
2 saws . . .	1	9	0	3	6
1 chalk line and reel .			0	0	6
2 pair compasses .			0	1	1
2 pair dogs . .	1	6	0	3	0
Chalk and bags .			0	1	3
Case for ditto . .			1	15	0
			6	2	7

Weight of each case.	cwt.	qr.	lb.
Saws . . .	0	2	12
Case . . .	0	2	13
	1	0	25

One set, containing:

			£	s.	d.
2 pit saws, 7ft. complete			1	16	0
1 cross-cut saw . .			0	11	0
2 saws . . .	1	9	0	3	6
1 chalk line and reel			0	0	6
2 pair compasses .			0	1	1
2 pair dogs . .	1	6	0	3	0
Chalk and bags .			0	1	3
Case for ditto . .			1	15	0
			4	11	4

One set, containing:

			£	s.	d.
2 pit saws, 7ft. complete			1	16	0
1 cross-cut saw, 6ft. .			0	13	3
2 saws . . .	1	9	0	3	6
1 chalk line and reel .			0	0	6
2 pair compasses .			0	1	1
2 pair dogs . .	1	6	0	3	0
Chalk and bags . .			0	1	3
Case for ditto . .			1	15	0
			4	13	6

	cwt.	qr.	lb.
Weight of saws . .	0	1	16
" chest . .	0	2	8
" Total . .	0	3	24

Nails.

			£	s.	d.
5 iron kegs of 50 lbs. each, 2 in. at per 100lbs.	19	6	2	8	9
5 ditto, 2½ in. . .	18	3	2	5	7½
5 ditto, 3 in. . .	16	9	2	1	10½
5 ditto, 4 in. . .	13	9	1	14	4½
5 ditto, 6 in. . .	13	0	1	12	6
Lettering ditto (per keg)	0	6	0	12	6
25 iron kegs . .	1	9	2	3	9
			12	19	4

GRINDSTONES.

		£	s.	d.
1 grindstone, 1s. 9d. spindle, 2s.		0	3	9
Case for ditto		0	8	5
		0	12	3

Four more the same.

Weight of each case	cwt.	qr.	lb.
Grindstone, &c.	0	0	21½
Case	0	0	17
Total	0	1	10½

TEN SETS MASONS' AND BRICKLAYERS' TOOLS,

Each containing :

	s.	d.	£	s.	d.
6 bricklayer's trowels	2	3	0	13	6
Pointing ditto			0	2	6
10 mason's chisels, 4 for soft stone, 6 for hard			0	16	3
10 do. points, 5 hard and 5 soft			0	11	1½
6 mason's hammers	3	0	0	18	0
2 mallets	2	10	0	5	8
6 bricklayer's chisels			1	3	0
6 pairs of line pins			0	3	0
3 iron squares	1	2½	0	3	7½
2 plumb rules and bobs			0	2	10
3 setting bars			0	7	7½
6 flat whitewash brushes			0	14	0
1 plastering trowel			0	2	5
3 foraging pails	15	9	2	7	3
3 painting ditto	1	6	0	4	6
3 spalling hammers	5	8	0	17	0
2 straight edges			0	2	3
1 spirit level			0	3	0
Case for ditto			2	4	0
			12	1	6½

	cwt.	qr.	lb.
Weight of tools	1	2	20
" chest	0	3	15
" Total	2	2	7

SIX SETS MINERS' TOOLS,

Each containing :

	s.	d.	£	s.	d.
2 striking hammers	4	0	0	8	0
1 crow-bar, 4 ft. 6 in.			0	4	6
1 ditto hollow, 3 ft. 6 in. light, 10 lbs.			0	3	6
1 copper pointed needle			0	4	0
1 ditto short			0	4	0
1 tamping bar			0	3	9
1 do. to suit light crow-bar			0	3	6
1 scraper or spoon			0	0	7
1 ditto			0	0	6
1 sledge hammer			0	5	8
1 set jumpers, sorted sizes, to suit light crow-bar			0	9	0
6 iron wedges, sorted	1	5	0	8	6
3 short handled pickaxes	2	10	0	8	6
2 field service shovels	2	2	0	4	4
3 push picks with wood handles	2	6	0	7	6
3 canvass buckets, 14in.	7	6	1	2	6
1 rope ladder			1	6	3
2 helves for shovels	0	7	0	1	2
2 ditto for pickaxes	0	7	0	1	2
2 hand borers	11	9	1	3	6
Case for ditto			2	1	0
			9	11	5

	cwt.	qr.	lb.
Weight of tools	2	1	18
" chest	0	2	22
" Total	3	0	12

2 chests . . . Nos. 1 & 2 Set.
2 ditto . . . 3 & 4 "
1 ditto . . . 5 & 6 "

Nos. 1, 3, 5, chests contain 2 shovels, 2 shovel helves, and 2 pick helves.

Loose — 6 hand barrows,

	s.	d.	£	s.	d.
5 bars	5	6	1	13	0
Weight each, 19¼ lbs.					
3 sets boring tools	70	0	10	10	0
3 ditto jumpers	5	3	0	15	9
3 ditto triangular ditto	5	3	0	15	9
3 worm augurs	7	0	1	1	0
3 chests for ditto	4	3	0	12	9
			13	15	3

Weight of each chest.—	cwt.	qr.	lb.
Tools	0	3	19
Chest	0	0	22
Total	1	0	13

Five Sets Coopers' Tools.

Each containing:

	£	s.	d.
1 crose, 4s.; 1 axe, 4s. 6d.	0	8	6
1 driver, 1s. 5d.; 1 hammer, 3 lbs., 2s. 3d. . . .	0	3	8
1 Jigger, 3s.; 1 adze, 3s. 3d.	0	6	3
1 Instrave, 2s. 10d.; 1 m tacks, 1s. 5d. . .	0	4	3
1 m rivets, 2s. 5d.; 1 pair compasses, 2s. 6d. . .	0	4	11
Chest for ditto . .	1	6	0
	2	13	7

	cwt.	qr.	lb.
Weight of tools . .	0	1	15
„ chest . .	0	1	10
„ Total . .	0	2	25

Loose—5 bundles iron hoops doubled in half lengths, each containing 50 lbs. each, ¾ in, 5s.; 1 in., 6s., 11 0	2	15	0
Bagging ditto . . .	0	7	6
	3	2	6

Weight of each bundle, gross, 3 qr. 27 lb.

Five Sets Armourers' Tools.

Each containing:

1 brace
1 plate and tap for side pins
1 ditto for tumbler
1 ditto for trigger
2 gauge bits, for side and breech pin
1 service bit
1 tumbler pin ditto
1 trigger ditto
1 round rymer
1 wood drill
1 drill socket
18 drills
1 breech pin grinder and plug
1 set side ditto, viz.—3 grinders, 2 guides, and plug
1 cup countersink
2 rose
1 stud
1 ditto grinder
1 trigger S. saw
1 pr. trigger pin grinders and plug
1 barrel float
1 groove
1 ramrod bit
1 centre
1 bolt saw and float
1 bolt slit saw
2 brace chisels
2 hand turn-screws
1 slit saw and back, each 6, 8, and 10 in.
1 breast plate
1 steel drill bow
1 drill string
1 pipe gouge
4 shovel tools
2 flue ditto
1 upright chisel
12 wood chisels
12 gouges
4 chisels and gouges for iron
1 brace nipple key
1 butt saw
1 draw knife
2 hammers and handles
1 scriber
1 breech wrench
18 files and handles
1 light vice
1 hand ditto
1 oil stone
6 wood awls
1 mallet
5 coils gut
12 spare handles

	£	s.	d.
Set of armourers' tools .	7	13	3
Case for ditto . .	1	5	0
	8	18	3

Weight of each case:	cwt.	qr.	lb.
Tools	0	2	8
Chest	0	1	18
Total	0	3	26

Eleven Sets Farriers' Tools.

Each containing:

1 hammer	1 rasp
1 pincers	1 paring knife
1 unclench	1 punch
1 buttress	

These complete . .	0	10	9
Case for ditto . .	0	9	6
	1	0	3

Weight of each Case.	lb.
Tools	8
Chest	14
	22

Reserve of Farriers' Tools.

	s.	d.	£	s.	d.
12 dozen rasps .	18	0	10	16	0
6 ,, knives .	13	0	3	18	0
			14	14	0

Miscellaneous.

	s.	d.	£	s.	d.
2 steelyards and weights to weigh 250 lbs. each	16	0	1	12	0
Case for ditto . . .			0	3	3
			1	15	3

	qrs.	lbs.
Weight of both. . .	0	26
,, case . .	0	19
,, Total . .	1	17

	s.	d.	£	s.	d.
5 lifting jacks .	45	0	11	5	0
5 cases for ditto .	3	9	0	18	9
			12	3	9

Weight of each case.	qr.	lb.
Jack	1	24
Case	0	23
Total . .	2	19

Loose—5 lifting jacks at 130s—£32 10 0
Weight of each—1 cwt. 1 qr. 13 lbs.

Twenty-four cases containing together:

	s.	d.	£	s.	d.
1,200 sets small hacking horse-shoes, 3¼ lb. per set . .	1	0	60	0	0
600 lbs. nails for ditto.	0	7	17	10	0
24 cases for ditto .	3	8	4	8	0
			81	18	0

	s.	d.	£	s.	d.
30 wheel-barrows complete . .	15	6	23	5	0
20 barrow wheels, spare			7	0	0
			30	5	0

	s.	d.	£	s.	d.
30 pair sap tools, to pattern . .	12	0	18	0	0
3 bundles wrappered, viz., one at 3s. 6d., two at 3s. . .			0	9	6
			18	9	6

1 bundle containing 30 sap forks to pattern.
2 ditto each 15 ditto 10 ft. long.

	s.	d.	£	s.	d.
10 pair spare handles for sap forks .	5	0	2	10	0

1 bundle contains 10 to pattern.
1 ditto 10, 10 ft. long.

	s.	d.	£	s.	d.
20 pair fascine chokers to pattern . .	6	0	6	0	0
1 bundle, wrappered .	3	9	0	3	9
			6	3	9

	s.	d.	£	s.	d.
30 park pickets to pattern, contained in 8 bundles .	5	2	7	15	0

	s.	d.	£	s.	d.
50 picket mallets to pattern . .	1	1	2	14	2
30 port-fire sticks .	1	11	2	17	6
2 cases . . .	6	3	0	12	6
			6	4	2

1 case contains 28 picket mallets with pattern enclosed.

1 case contains 22 ditto, 30 port-fire sticks, with pattern of ditto.

	s.	d.	£	s.	d.
20 fascine mallets to pattern, contained in 5 bundles of 4 each	2	5	2	8	4

INTRENCHING TOOLS SUPPLIED FOR THE USE OF THE TURKISH CONTINGENT ENGINEERS, BY WALTER A. LYNDON, OF BIRMINGHAM.

Marked T. C. E.		£	s.	d.	Cost of Package. £	s.	d.
1 to 40	40 Casks, each containing 100 Cast Steel Pick-axes, 5lb. each, at 1s. 8d.	333	6	8	15	0	0
41 to 50	10 Casks, each containing 100 Cast Steel Pick-axes, 6½lb. at 2s. 2d.	108	6	8	4	2	6
51 to 60	10 Casks, each containing 50 Cast Steel Felling Axes, handled, at 5s. 4d.	133	6	8	5	0	0
51 to 65	5 Cases, each containing 100 Cast Steel Hand Axes, handled, at 1s. 11d.	47	18	4	1	10	0
	450 Bundles, each containing 10 Patent Field Shovels, at 2s. 0d.	450	0	0	11	5	0
	50 Bundles, each containing 10 Patent Spades, at 2s. 9d.	68	15	0	1	5	0
	192 Bundles, each containing 25 Handles for 5lb. Pick-axes, at 7d.	140	0	0	4	16	0
	48 Bundles, each containing 25 Handles, for 6½lb. Pick-axes, at 7d.	35	0	0	1	4	0
	4 Bundles, each containing 25 Handles, for Felling Axes, at 1s. 3d.	6	5	0	0	2	0
					1,322	18	4
					1,367	2	10

Measurement of each Package.		Total Weight. ton.	ct.	qr.	lb.
40 Casks, 30 × 25 in.	about	9	12	0	0
10 Ditto, 32 × 27	„	3	3	0	0
10 Ditto, 43 × 15 × 15	„	1	12	0	0
5 Ditto, 30 × 15 × 15	„	0	7	2	0
500 Bundles, spades and shovels, 41 × 10 × 9	„	11	0	0	0
192 Bundles of pick-axe handles, 34 × 11	„	4	0	0	0
48 Ditto, 36 × 11	„	1	0	0	0
4 bundles of axe handles, 36 × 14	„	0	1	1	0

PONTOONS, &c., SUPPLIED TO THE TURKISH CONTINGENT ENGINEERS, BY DEAN, DRAY, AND Co., LONDON BRIDGE.

	£	s.	d.	£	s.	d.
64 strong tin pontoons 23ft. 10in. long, 2ft. 8in. in diameter, with air-tight compartments, wheels, and axles, inside; painted red inside and out; gun-metal handles and rings, and plates at end	at 40	10	0	2,592	0	0
Extra for turning gun metal handles and fitting with tinned copper barrels, 1,280 handles	0	0	11	58	13	4
Extra for swivel rings, with gun-metal eyes and washers riveted on plates on 52 pontoons	0	5	4	13	7	4
64 gun-metal keys for plugs of pontoons	0	1	0½	3	6	8
32 copper pumps	0	12	6	20	0	0
				2,687	17	4

Pontoon Wagon-Bodies and Fittings, and Superstructure of Bridge, Supplied by W. Dray and Co, London.

32 Wagon Loads of Pontoon Superstructures, each Load consisting of:

1 anchor.	3 body lashings.
12 baulks.	4 carriage ditto.
1 buoy.	8 rack lashings and sticks.
1 boat-hook.	4 saddle ditto.
10 chesses.	60 feet buoy line.
4 half ditto.	60 feet breast ditto
168 feet cable.	7 oars, 2 saddles.
3 tender bodies and girths.	5 side pieces.

As per estimate—£1,460.

	£	s.	d.	£	s.	d.
32 pontoon wagons on springs, with one skidpan and chain to each, also shutting and fitting axles to ditto (the wheels and axles supplied by W. Crosskill) . . at	30	0	0	960	0	0
Painting ditto	1	10	0	48	0	0
32 extra springs	1	18	0	60	16	0
32 extra skidpans	0	4	0	6	8	0
32 screw hammers	0	6	0	9	12	0
6 pair extra scroll irons	0	10	0	3	0	0

Wagons, Carts, &c., Supplied to Turkish Contingent Engineers, by W. Crosskill, Iron-Works, Beverley.

	£	s.	d.	£	s.	d.
C—24 wagons for carrying intrenching tools, fitted up with partitions and straps as described; wheels 4 ft. 2 in. high, 3-in. tire . . . . at	48	0	0	1,152	0	0
I—16 carts for carrying intrenching tools, fitted up with partitions and straps; wheels 4 ft. 2 in. high, 3-in. tire	25	0	0	400	0	0
A—6 wagons for carrying artificers' tools, plain bodies without sides; wheels 4 ft. 2 in. high . .	40	0	0	240	0	0
G—6 carts for carrying artificers' tools; wheels 4 ft. 9 in. high	18	0	0	108	0	0
B—7 wagons for carrying spare stores, constructed like those marked C, but without partitions and straps .	42	0	0	294	0	0
H—11 carts for carrying spare stores, constructed like those marked I, but without partitions and straps .	20	0	0	220	0	0
32 sets of wheels and axles for pontoon wagons . .	19	0	0	608	0	0

Field Forges Supplied to the Turkish Contingent Engineers, by J. C. Onions, Birmingham.

	£	s.	d.
8 portable forges to pattern, with anvils, blocks, hammers, paddles, &c., complete, at £20	160	0	0
2 improved large extra powerful field forges, No. 200, at £12 12s. .	25	0	0
2 best warranted vices fitted to large forges, at 25s. . . .	2	10	0
	187	10	0

WAGONS, STORES, &c., SUPPLIED FOR THE TURKISH CONTINGENT ENGINEERS, BY HERBERT AND ARTHUR HOLMES, DERBY.

	£ s. d.	£ s. d.
Photographic wagon as per estimate		85 5 0
144 spare grease cans with straps and knives . .	at 0 4 4	31 4 0
Filling ditto with Australian grease, 3½ lbs. each, 504 lbs. .	0 1 9	44 2 0
40 pack saddles to the pattern now adopted by the Ordnance, with head stall bridles, leading reins, and oiled cloth covers complete	4 10 0	180 0 0
A spare set of wheels for wagon painted and brushed complete		11 0 0
A spare set of springs for ditto with eye-bolts and D shackles		5 10 0
A spare pair of springs, with bolts and braces complete, and 3 extra pair of leather braces		3 5 0
Supplied to Mr. Crosskill, Beverley.		
4 patent tire bars 2 cwt. 2 qrs. 2 lbs.	0 11 6	1 8 11
4 ditto ditto 2 2 4	0 11 6	1 9 2
Patent right on the above, per ton	0 10 0	0 2 7
160 bars 15 ft. 3 in. long, 5 tons 4 cwt. 0 qrs. 16 lbs. weight		
262 bars 13 ft. 6 in. „ 7 tons 11 cwt. 3 qrs. 15 lbs. „		
12 tons 16 cwt. 0 qrs. 3 lbs. „	———	147 4 4
Patent right on ditto, at 10s. per ton		6 8 0
		516 19 0

	£ s. d.
The fittings of electric telegraph wagon (as per order of Capt. Beaumont) for the Turkish Contingent Engineers, supplied by the Electric Telegraph Company, Lothbury, City, cost	174 19 0

	£ s. d.
Four Groves's Voltaic Batteries, &c., supplied for Turkish Contingent Engineers' Electric Telegraph Wagon, by George Knight and Sons, cost	32 12 0

	£ s. d.
The Photographic Apparatus of the Turkish Contingent Engineers, cost	64 4 4

DISTRIBUTION OF WAGONS AND CARTS.

Company.	Wagons.						Carts.			Pack Mules.	Remarks.
	Flat. A	Store. B	Intrenching Tools. C	Pontoon. D	Electric Telegraph. E	Photograph. F	Flat. G	Store. H	Intrenching Tools. I		
1.	2	2	-	-	1	1	2	4	-	16	
2.	1	1	12	-	-	-	1	2	8	6	
3.	1	1	12	-	-	-	1	2	8	6	
4.	1	1	-	16	-	-	1	2	-	6	
5.	1	1	-	16	-	-	1	2	-	6	

The 1st Company, being intended to act as a reserve at head-quarters, received thus a larger supply of artificers' tools and stores, and had, moreover, the scientific apparatus and the India-rubber boats.

INDIA-RUBBER BOATS, AND STORES FOR THE REPAIR OF THE SAME, FOR THE TURKISH CONTINGENT ENGINEERS, SUPPLIED BY C. MACINTOSH AND CO., CANNON STREET, CITY, LONDON.

	£	s.	d.
Ten India-rubber air-proof boats, with 8 compartments, as per pattern exhibited to Major Stokes, complete, with sculls, &c., at £38 .	380	0	0

Ten stout Twill Bags, containing each :

3 yds. 42 in. sheeting.
3 yds. 42 in. linen canvass coated on both sides
3 yds. 42 in. sheeting, air-proof ditto.
3 yds. 42 in. cotton canvass.
$12\frac{1}{2}$ yds. 42 in. grey calico, rolled in the above.
10 cans of solution.
2 flasks of naptha, 2 ditto turpentine.
1 can of French chalk.
2 sheets of rubber.
$\frac{1}{2}$ yd. varnished gauze to secure the cans.
$1\frac{1}{2}$ yd. grey sheeting.
4 pair bellows' nozzles, 8 air valves.
10 short rollers.
1 small bag containing two pair of bellows.

One wood box, containing:

2 iron rollers, 2 wood ditto.
2 milling wheels, 2 pair large scissors.
2 7-in. knives, 2 5-in. ditto, 3 sharpening stones.
6 round varnish brushes, 6 flat ditto.

All the foregoing 12 packages . . £50 0 0

	s.	d.	£	s.	d.
Extra leather, eyelets, punches, &c., for repairs if required, viz.— 18 lbs. leather, 50 large tinned eyelets, 50 medium, 50 small, 6 wadding punches, 6 eyelet beds, turned, 5 riveting punches			6	0	0
150 yds. canvass for cases to contain boats . . .	1	$0\frac{1}{2}$	7	16	3
30 yds. ditto	0	$8\frac{3}{4}$	1	1	11
Straps and buckles attached to canvass bags, as per Saddlers' invoice			7	13	6
Needles, cord, &c., for men making bags . . .			0	4	9
			452	16	5

STORES FOR RESERVE.

	£	s.	d.	£	s.	d.
Sand bags, twenty thousand	at 0	5	0	416	13	4
Bickford's patent fuze, 150 coils, 24 fathoms each . .	0	6	0	45	0	0
Iron, ten tons of all sorts	11	0	0	110	0	0
Steel, two tons, cast, wrought, and blister . . .				120	0	0
Nails, three tons, all sizes				180	0	0
Chain, $1\frac{1}{2}$ ton, ditto				45	0	0
Lifting jacks, five in cases, £12 10 0, five loose, £32 10 0				45	0	0
Pile engines, two complete				150	0	0
Steelyards, &c.:						
Eight steelyards and weights at 17s. 6d.	7	0	0			
Five Salter's balance weights	6	5	0 —	13	5	0
Locks, &c.:						
Five hundred padlocks at 3s.	75	0	0			
Five hundred dead-locks and one hundred stock-locks, 3s. 6d.	105	0	0 —	180	0	0
Tents:						
Ten office marquees, at £11 15 0	117	10	0			
Ten officer's ditto	117	10	0			
Mess tent	14	10	0			
Twenty-six circular tents, at £4 5 0 . . .	110	10	0 —	360	0	0

Wagons and Carts:

	£	s.	d.	£	s.	d.
Ten wagons without sides, for carrying tools	400	0	0			
Ten ditto for carrying timber, all sizes	300	0	0			
Ten carts without sides, for carrying stores	200	0	0			
Ten wagons with sides, for carrying stores	480	0	0			
Ten slush carts, with scoops	100	0	0			
Fifty spare wagon poles	75	0	0			
Packing fifty wagons and carts	25	0	0	1580	0	0
Oakum, 10 cwt.				15	0	0
Tarred spun yarn, 10 cwt.				30	0	0
Paint and tar brushes, one hundred				7	10	0
Whiting, 10 cwt.				2	10	0

Grease, Tallow, Oil, &c.:

	£	s.	d.	£	s.	d.
5 cwt. Holme's antiatrition	7	10	0			
10 cwt. dubbing, at 25s.	12	10	0			
5 cwt. tallow, at 30s.	7	10	0			
Sperm, linseed, and drying oil, fifty gallons of each.	75	0	0	102	10	0

Tarpaulins:

	£	s.	d.	£	s.	d.
Fifty 24×12 ft., ten 40×20 ft., equal to 2,500 square yards.	0	2	7½	328	2	6

Mathematical Instruments, &c.:

	£	s.	d.	£	s.	d.
Two chronometers, at £45	90	0	0			
Six measuring chains at £1	6	0	0			
Twenty-five measuring tapes, at 12s.	15	0	0			
One pentagraph	5	0	0			
Eight card protractors, at 5s.	2	0	0			
Four prismatic compasses, at £4 4 0	16	16	0			
				134	16	0
Photographic apparatus, stores to complete the same				5	0	0
Waterproof boots, fifty pairs	1	10	0	75	0	0
Hedger's gloves, one hundred pairs	0	1	6	7	10	0
Leather, various kinds and thicknesses				100	0	0
				4,052	16	10

	£	s.	d.	£	s.	d.
Carpenter's tools	910	13	5			
Smith's and tinman's	132	0	10			
Sawyer's	76	10	0			
Collar and shoemaker's	89	12	5			
Miner's	330	16	0			
Mason's and bricklayer's	172	16	10			
Intrenching tools	663	6	8	2375	16	2
Total.				6428	13	0

NOTE.—The numbers of articles here enumerated have been *generally* approved of by the Permanent Engineer Committee at Chatham, but the *distribution* of the chests, &c., which they recommend is very different from that of the Turkish Contingent Equipment, and is given in the Notes on the Construction of Batteries, &c., lately printed at Chatham.—ED.

Instruments for Scientific Purposes.

Name of Instruments.	Maker's Name.	Usual Selling Price.			Price Supplied to Government.		
		£	s.	d.	£	s.	d.
Vidis improved barometer, with scale divided to 100, in black sling case	Elliott	5	10	0	4	14	6
Artificial horizon	ditto	1	11	6	1	8	0
Standard barometer	ditto	11	0	0	10	0	0
Deal case for do., marked "Turkish Contingent"	ditto	0	8	6	0	7	6
Gay Lussac's mountain barometer in sling case	ditto	6	16	6	6	0	0
50 ft. chain and arrows in bag	ditto	1	0	0	0	17	0
Prismatic compass with azimuth glass and sun shade, in sling case, with legs . . .	ditto	5	15	6	5	5	0
Improved ditto for vertical angles . . .	ditto	6	16	6	6	0	0
Beam compasses	ditto	1	11	6	1	8	0
Mason's hygrometer, in box	ditto	1	0	0	0	18	0
Case of instruments	Gogerty	3	10	0	3	0	0
Spirit level, Improved Gravatt's Dumpy, fitted to theodolite legs	Elliott	13	13	0	12	10	0
Set of levelling staves	ditto	5	5	0	4	10	0
Case to hold staves, legs for theodolite, and steel straight edges	ditto	1	0	0	0	18	0
2 micrometer Rochons							
Payne's Patent Pedometer	ditto	4	4	0	4	0	0
Perambulator	Gogerty	12	0	0	8	0	0
Ditto, with iron wheel and case for index. .	Elliott	5	15	6	5	0	0
Sketching protractor	Gogerty				0	17	0
Parallel rules	ditto				0	14	0
Set of brass scales	Adie				5	14	0
Sextant	Elliott	10	10	0	9	10	0
Ditto	Dennis	15	0	0	13	5	0
Leather case for ditto	Elliott	1	5	0			
Pocket sextant, with telescope in sling case .	ditto	5	0	0	4	10	0
Set Holtzapffel's Scales of equal parts . .	ditto						
Steel straight edge divided into French and English measures	ditto	2	5	0	2	0	0
50 feet tape	ditto	0	9	0	0	8	0
Steel die	ditto	1	17	6	1	14	0
Station pointer.							
Improved very powerful night glass in sling case	ditto	5	15	6	5	0	0
5-in. best French theodolite, divided on silver with tangent and screw adjustments . .	ditto	25	4	0	22	0	0
Travelling standard thermometer . . .	ditto	2	5	0	1	15	0
Metal thermometer in wood case . . .	ditto	0	12	0	0	10	0
Woolaston's thermometrical barometer . .							
2 Tastre's Standard thermometers . . .							
Leather case for theodolite, No. 1 . . .	ditto	1	1	0	0	19	0
Ditto for No. 2	ditto	1	1	0	0	19	0
Ditto for level	ditto	1	9	0	1	6	0

Reference and Map Cases cost . . . £7 6 6

PAPER XXIV.

Report on the Operations of the Engineers at the Taking of the City of Kotah, in March, 1858.

By LIEUT. COL. TREMENHEERE, Bombay Engineers.

Letter from the Commanding Engineer to the Assistant Adjutant General, Rajpootana Field Force.

Camp Kotah, 5th April, 1858.

Sir,—I have the honour to furnish the following summary of the Engineering operations at the taking of the City of Kotah, for the information of Major General Roberts.

The Force arrived before the place on the 22nd March, and encamped a short distance from the left bank of the river, behind the village of Suckutpoor. It was known that the Raja was in possession of that portion of the city nearest the palace, and of the fortified line of wall which separated it from the rest of the city; that he was willing to place the defence of the place in our hands, and to allow the immediate entrance of European troops. On an inspection of the river, which was at once made, it was ascertained that no difficulty would be experienced in crossing over any portion of the Force, opposite the palace, and that the boats in the Raja's possession were capable of conveying heavy artillery. Some large buildings in the city had been already prepared by the Raja for the reception of troops.

Captain Cumberland and Lieutenant Haig reconnoitred the left bank of the river below the Village of Suckutpoor, and Captain Cumberland fixed upon two sites for batteries: No. 1, near Suckutpoor, for two 12-pdr. iron guns, to keep under the fire of the enemy's guns directed upon the ferry; and No. 2, near the Village of Kinaree, for two 18-pdr. guns, to oppose a battery of the enemy on the other bank, and to draw their attention towards that end of the city. Both these batteries were commenced during the night of the 22nd.

On the morning of the 23rd, I inspected the whole of the works held by the Raja's troops, and on my return laid before the Major General a plan for assaulting the place, but it had not then been determined whether the force should move across the ford at Gamuch, and attack the enemy in their cantonment outside the city, or take advantage of the position offered to us within.

24th March.—The batteries were completed and armed during the night of the 23rd, and fire was opened from them at daylight on the 24th. In addition to the heavy guns in the batteries, two 8-inch mortars were placed in rear of each, and fired occasionally at the large buildings in the city, and at a conspicuous haystack which the enemy were subsequently observed to set fire to. Battery No. 1 appeared completely to accomplish the object intended, as the enemy very rarely ventured to fire a shot from their battery bearing on the ferry; but the fire of the enemy's guns on No. 2 was well sustained throughout the whole period, and was never entirely overcome.

25th March.—At daylight on the 25th, heavy firing was heard in the town, occasioned by a bold and vigorous assault by the enemy with scaling ladders upon the Patenpole Gate, and the works held by the Raja's troops in its immediate vicinity; the firing continued for a considerable time and the enemy were repulsed with loss. On the afternoon of this day I was directed, in company with the Officer Commanding the Artillery, to inspect the works held by the Raja, and to decide upon the position and description of the artillery which could be mounted thereon, to assist in carrying out the plan for obtaining possession of the city as originally proposed.

A detachment of two companies of Her Majesty's 83rd Regiment, and one company 13th Regiment of Native Infantry, were, late in the evening, sent across the river to assist in the defence of the town. A party of Royal Engineers, consisting of 20 rank and file, under Captain Cumberland, was also sent to make the roads from the landing places on the river-bank to the points at which artillery would be required, practicable for guns.

It having now been determined that the 12-pdr. guns in No. 1 Battery should be withdrawn, and placed in position in the town, and that troops for the assault should be sent across the ferry, it was resolved to place two 18-prs. in a position commanding the enemy's battery on the opposite bank, from which fire was still occasionally opened upon the ferry; a site was accordingly selected for Battery No. 4, and the work was commenced at night. From its position and the slackness of the enemy's fire it was not necessary to raise the parapet higher than the soles of the embrasures, and the battery was completed early on the following day.

26th March.—The fire from the enemy's guns on the left being still unsubdued, an 8-inch howitzer was placed behind a parapet near Battery No. 3 on the left, to assist in disabling the enemy's guns. In the evening the 12-pdr. guns and the whole of the 8-inch mortars in battery were withdrawn. The former were taken across the river during the night, and the latter removed to the park preparatory to being sent into the town. It was considered advisable to continue the fire on the left during operations within the town, and No. 5 for three guns was commenced this evening on the north side of the Village of Kinari, in a position commanding the landing places at Lallpoora, and was completed early on the morning of the 27th; during the night a party of Royal Engineers, under Lieutenant Paterson, was employed in opening three embrasures in the Lall Bastion.

This bastion, situated in an angle on the line of works held by the Raja, commands a wide opening in its front, communicating with a tank within the city walls, across which is the only line of communication between that portion of the city near the Soorujpoor Gate and Rampoora.

27th March.—At 10 A.M., on the 27th, the enemy made another assault upon the town, but were driven back by the garrison, and by part of the detachment of Her Majesty's 83rd Regiment.

28th March.—During the 27th and 28th the following ordnance were got into position in the town.

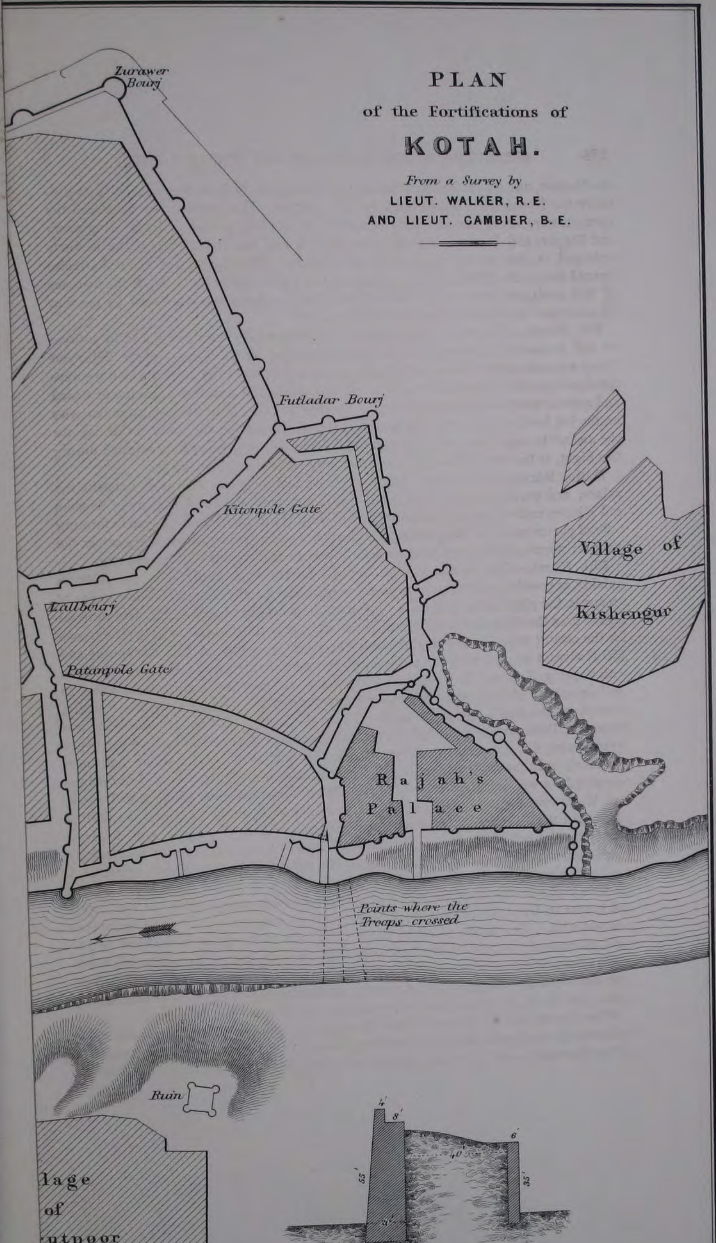
In the Lallboorj, one 12-pdr. heavy gun, and one 24-pdr. howitzer; below the rampart, near the Lallboorj, three 8-inch mortars; near the Kittonpole Gate, two $5\frac{1}{2}$-inch mortars belonging to the Mountain Train; on a bastion next to the Puttardar Bastion, and on the rampart below, two Mountain Train howitzers; on the right, below the Hooniman Bastion, three 8-inch mortars. Embrasures were made and the parapets were strengthened, where necessary, by working parties of Royal Engineers and Sappers and Miners. Ramps were formed, and the terrepleins of the bastions enlarged, to give more room for working the guns. The 12-pdr. gun in the Lallboorj opened fire on the 28th upon some guns behind a stockade in its front, at the distance of 300 yards, and on the other side of the river slow firing was continued by the four 18-pdr. guns in the batteries on the right and left.

29th March.—The whole of the guns and mortars which had been placed in position on and in rear of the works in the town, opened fire about 6 A.M., on the 29th, and firing was maintained throughout the day on that portion of the city in which we were informed the chief magazine was situated, and at about 5 P.M. the magazine exploded and several minor explosions followed. The fire was also continued from the batteries on the left bank of the river. Orders were issued during the afternoon of this day for the assault to take place on the morrow, and firing was ordered to be continued during the night, at the rate of 2 rounds per hour from each piece of ordnance.

During this day the bridge equipage was moved down to the river bank opposite the palace, and working parties from the Royal Engineers, and 3rd Company of Sappers and Miners, under Captain Cumberland and Lieut. Hancock, were employed in forming rafts of porter casks for the passage of Infantry, and in passing three cables across the river for warps; these arrangements were successfully completed by the evening.

30th March.—The Artillery were ordered to fire from daylight on the 30th as quickly as possible, while arrangements were made for the assault. The number of troops in the city had been increased early in the morning to 2,000 men, who were all passed over the river on the rafts and boats without accident or casualty. The troops for the assault were formed in three columns, each consisting of 250 Europeans and 250 Natives, a column of the same strength being left in reserve. 2 Engineer Officers, with a party of Royal Engineers carrying tools and powder bags, were attached to each assaulting column, and two scaling ladders, carried by a party of Native Sappers, to each of the two leading columns. The 3rd Column was accompanied by two Mountain Train howitzers under Lieutenant Heathorn of the Artillery. When every arrangement for the assault had been made, the Kittonpole Gate, which had been previously built up with stone, the chief part of which had been removed during the morning by a working party supplied by the Mina Battalion under Captain McDonald, was blown open by two charges of powder laid against it, which produced the desired effect, and the leading column entered the city at half-past 11 o'clock A.M., followed closely by the other columns. The manner in which the assault was successfully carried out will have been fully reported by the officers in charge of each column. I need only observe that by moving the columns to the south, under the rampart of the enemy's works on that side, the whole of the enemy's defensive positions in the streets and houses in front of the Kittonpole Gate were turned, and no material resistance was met with. The retreat of some of the chief men of the place was cut off by the rapid advance of the 1st Column on the Soorujpoor Gate, and as they defended themselves obstinately in a large house, a party of Royal Engineers under Lieut. Paterson, were employed to dislodge them by blowing up the house; charges were successively placed, and fired, in various parts of the house, and the defenders destroyed.

When the success of the assault was ascertained, and the enemy were seen to be precipitately evacuating the city, the column in reserve was directed to enter Rampoora by the Patenpole Gate: the 2nd column also marched towards the north end of the


PLAN
of the Fortifications of
KOTAH.
From a Survey by
LIEUT. WALKER, R.E.
AND LIEUT. CAMBIER, B.E.
Zurawer Bourj
Futladar Bourj
Kitonpole Gate
Lallbourj
Patanpole Gate
Rajah's Palace
Village of Kishengur
Points where the Troops crossed
Ruin
lage of utpoor
4'
8'
6'
40
55'
35'
SECTION ON C. D.

city, which was found to be entirely abandoned by the enemy, and occupied Rampoora and Lallpoora gateways. On taking possession of one of the enemy's batteries, opposite the Village of Kinari, Colonel Holmes, in command of the 2nd Column, ordered Lieutenant Hancock, with the party of Royal Engineers under his orders, to dismount the guns; while so employed the magazine in the battery blew up, and I regret to state that Lieutenant Hancock and ten men of the Royal Engineers, and three of the 12th Regiment of Native Infantry, were more or less severely injured, and that four of the Royal Engineers have since died of their wounds.

In concluding this report I feel it incumbent upon me to bring to the especial notice of the Major General the very exemplary conduct of the officers and men under my command, throughout the period during which these operations lasted; nothing could exceed the cheerful alacrity with which the non-commissioned officers and men of the 11th Company of Royal Engineers performed their very arduous duties, and I am happy to say that the Native Sappers emulated the conduct of the Europeans, and were particularly noticed for their coolness when called upon to perform duties in situations much exposed to the enemy's fire.

The work fell very heavily upon the officers, only six in number, and although occasionally they were on duty twice in the same day, they were ever ready to undertake it with the greatest cheerfulness.

To Captain Cumberland my thanks are especially due for the very valuable assistance he rendered to me throughout. Lieutenants Walker and Paterson, of the Royal Engineers, and Lieutenants Haig, Hancock, and Gambier, of the Bombay Engineers, equally distinguished themselves by their ready compliance with every call of duty, and by their careful execution of every order they received. Lieutenant Haig's duties were especially arduous, as from the paucity of officers, he voluntarily undertook, in addition to his duties of staff officer, to share the duties in the trenches with the other officers.

I have the honour to be, &c.

(Signed) C. W. TREMENHEERE,

Major, Commanding Engineer, Rajpootana Field Force.

PAPER XXV.

On Aneroid and Mercurial Barometers, with a New Table for Facilitating Calculations for Altitudes.

By SAMUEL B. HOWLETT, Esq.,

Chief Draughtsman in the Office of The Inspector General of Fortifications, and Inspector of Instruments, Tower.

When the Aneroid Barometer is intended to be used for the measurement of altitudes, the whole circle on the plate should be divided into eight parts, numbered 31 to 24, each part representing an inch on the mercurial barometer, and each inch divided to tenths and hundredths. The hand should be finely pointed, and should nearly touch the graduations, in order that the readings may be taken correctly to hundredths, and to thousandths by estimation. The Aneroid should be compensated for temperature.

Attempts have been made to attach verniers to these instruments; but as the vernier has to be centred on the glass plate, and must have an external handle, it is, upon the whole, better omitted. The register hand, the attached thermometer, and the words "Fair, Change, Rain," though of no use for the present purpose, may be retained, to make the instrument more useful when employed as a common hall barometer.

As the form of the instrument renders it very liable to slip from the hand, especially when used on horseback, the ring should be large enough to admit the thumb with a glove on. The case should be large enough to allow of the instrument being easily taken out, and replaced. A black water-proof leather case, with strap for the shoulder, should be chosen.

At the back of the aneroid will be noticed a screw, which is for the purpose of setting the hand to read exactly with another aneroid, when they are intended to be used by two observers, one at the datum station, while the other takes a circuit of observations in the vicinity. The maker should set the aneroid to read accurately with a standard mercurial barometer.

If the aneroid acts correctly, it will read all round the eight inches exactly the same as a mercurial barometer, when both are placed under an air-pump, the object of this portable elegant contrivance being to rival the mercurial barometer. If upon this comparison any discrepancies appear, they should be noted, and given with the instrument.

It is necessary to be provided with a good portable thermometer, for the purpose of taking very accurately the temperature of the air, which should always be taken in the shade. The degrees according to Fahrenheit are those used in the following table; but it is as well to have the degrees of the Centigrade also marked on the scale, for the purpose of entering both in the field-book, as a check against error.

In practice, if a person is on foot, the best way is to place the aneroid flat on the ground, and then, having tapped it a little, to read it with a magnifier, if necessary. On horseback, it may be rested on the withers of the horse; and it may be conveniently used when placed with the thermometer on the seat of a carriage.

When employed for determining heights, the aneroid must be used, and the observations calculated, upon the same principles as are necessary for the mercurial barometer. The most perfect formula for this purpose at present known, is that by the late Mr. Francis Baily; but to use this formula logarithms must be employed.*

But since the invention of the aneroid many attempts have been made to provide an easy popular method of calculating altitudes from observations taken with it; and, for this purpose, the following Table of variable coefficients is submitted as being, it is believed, more simple, correct, and universal, than any of the approximate kind that has yet appeared, as will be found upon trying it fairly by rigid calculations.

In all states of the barometer and thermometer this table will answer correctly for any altitude where the half sum of the observations at the upper and lower altitudes is not less than twenty-six inches, which includes a range beyond that of the aneroid, and is sufficient for determining altitudes of eight or ten thousand feet above the sea.

TABLE AND RULE FOR MOUNTAIN BAROMETERS.

A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	C.	In 100.
26·0	1057	27·0	1017	28·0	977	29·0	943	30·0	911	0°	+·27
·1	1053	·1	1013	·1	973	·1	940	·1	908	10	+·25
·2	1049	·2	1009	·2	969	·2	936	·2	905	20	+·20
·3	1045	·3	1005	·3	966	·3	933	·3	902	30	+·14
·4	1041	·4	1001	·4	963	·4	930	·4	899	40	+·06
·5	1037	·5	997	·5	959	·5	927	·5	896	45	—
·6	1033	·6	993	·6	956	·6	924	·6	894	50	—·05
·7	1029	·7	989	·7	953	·7	921	·7	891	60	—·13
·8	1025	·8	985	·8	949	·8	917	·8	888	70	—·20
·9	1021	·9	981	·9	946	·9	914	·9	885	80	—·25

EXAMPLE.—Suppose the following observations, in Lat 60°.

	Lower.	Upper.
Barometer	30·826	21·220
Mercury . . .	55°	40°
Air	55°	40°

Lower . .	30·826	55°
Mercury (55°—40°)	·046	40
Lower, corrected	30·780	95
Upper . .	21·220	100
	2) 52·000	5
Half sum . .	26·000	
Difference . .	9·560	

B . .	1057
	5
B′ . .	1052
	9·56
	10057
	Lat. 13
Altitude	10044 Feet.

RULE.—When aneroids are used, correct the observations for irregular action according to data given by the maker.

When mercurial barometers are used, reduce each observation to the lowest temperature of the mercury that occurred, by deducting from each above that temperature, 1-10,000th part of itself for every degree (Fahrenheit) of difference of temperature.

* A very carefully computed Table from Baily's formula will be found in Vol. 1, of the R. E. Papers, published in 1837.

Add together the corrected readings of the instruments at the lower and upper stations, and take half their sum ; and take their difference.

Find the half sum in A, and take out the number against it in B, interpolating when necessary.

Take the difference between 100 and the sum of the temperatures of the air at the two stations; and if the sum of the temperatures is greater than 100, add the difference to B, but if less, subtract it from B, and call the result B′.

Now multiply B′ by the difference between the stations, and the product will be the approximate altitude in feet.

Opposite the Latitude in C, is the correction per cent. to be applied to the approximate altitude.

It may now be acceptable to give a few additional examples, so contrived as to suggest the best methods of using the aneroid when either one or more persons are employed; and the same principles apply equally to the mercurial barometer.

1. A person went on shore in latitude 70° with an aneroid and a thermometer, to find the height of a mountain. At high-water mark the aneroid was 29·63 inches, the air 54°. At the top of the mountain the aneroid stood at 27·35, the air 50°. On his return to high-water mark, the aneroid was 29 67 (showing that the barometer, since his first observation, had risen ·04 inch), and the air 58°. What was the altitude ?

At high water-mark	29·63	Air	54°	B . .	959
Ditto . . .	29·67		58		6
	2)59·30		2)112	B′ . .	965
Mean	29 65	Mean	56		2·3
Mountain . . .	27·35		50		2895
	2)57·00		106		1930
Half sum	28·5		100		
Difference . . .	2·3				2219·5
			6	Lat.	4·4
					2215·1 Alt.

2. An officer went on shore in latitude 10°., with an aneroid and a thermometer, to take the heights of three hills, x, y, and z, and ordered that the boat should meet him a few miles round a point. On landing, at 10.30, he placed the aneroid on high-water mark, and it read 29·15, and the thermometer 63°. At 11.30, he found, at the summit of x, that the aneroid was 28·5, the air 55°. At y, at 12.0, aneroid 27 65, air 52°; and z, at 12.20, aneroid 28·72, air 60°; and again at high-water mark, near his boat, at 12.40, he found the aneroid had fallen to 29·08, and that the thermometer had risen to 66°. Required the altitudes of these hills.

Now, as the high-water line may be assumed to be level, there was no necessity, in this case, to return to the first station to ascertain the change in the barometer since the first observation ; and we see that between 10.30 and 12.40 the barometer had fallen ·07 inch, and that the thermometer had risen 3°. Hence, interpolating according to time, we have—

	29·15		63°	B . .	949
Change	·03	change	1		19
	29 12		64	B′ . .	968
	28·50		55		·62
2)	57 62		119		600·16
			100	Lat.	1·50
	28·81				
	·62		19		601·66 Alt. x.

By a similar process will be found $y = 1426$, and $z = 360$ feet.

3. Two persons arranged to take the altitudes of six hills above a station A, in latitude 50°. They set their aneroids and watches to read together, and each was provided with a thermometer to take the temperature of the air. One remained at A, to take the readings of the aneroid and thermometer, whenever any change was visible, noting the time; while the other went on horseback to take similar observations on the summits of the six hills; and the following is a copy of his field-book:—

Stations.	Time.	Aneroid.	Air.	Altitudes.
1	10.15	29·35	38°	382·9
2	11.0	29·41	39	325·4
3	11.40	29.30	38	419·9
4	12.10	29·12	39	581·8
5	12.20	29·345	37	374·7
6	12.35	29·14	37	572·0

The following is a copy of the observer's book at A, from which, however, only those times are copied which answer most nearly to the times of observation in his companion's book:—

A.	Time.	Aneroid.	Air.
1	10.11	29·774	40°
2	11.2	29·770	41
3	11.40	29·764	41
4 and 5	12.17	29·760	41
6	12.39	29 772	40

These two books give, respectively, the observations at the lower and upper stations, from which the altitudes annexed to the stations in the field-book were calculated, and which will serve as six other illustrations, if they be worked out. In working them out, instances of interpolation will be found in Nos. 1, 3, and 4. In No. 1, for example, the half sum is 29·562, which falls in column B between 927 and 924, the difference between these being 3. Hence B is 925; for, in apportioning this 3, we see at once that 2 must be given to ·062, the proportion, strictly, being 100 : 62 : : 3 : 1·86, which may be called 2 in low altitudes. In this example the corrections for latitude may be neglected.

In all the foregoing remarks I have chiefly had in view the Aneroid, when used as an Orometer; but I now proceed to submit some remarks on the mercurial barometer. In the first place, it must be premised that the system of using both these instruments in the measurement of heights is essentially the same, and so is the method of making the calculations; and therefore nothing now remains to be done but to point out the peculiarities of the mercurial barometer as compared with the aneroid.

The construction of the mountain barometer that is most generally preferred, is that by M. Gay-Lussac. This barometer is a glass syphon, contained in a brass tubular scale, having the zero at the bottom, and divided upwards to 33 inches. Each inch is divided into tenths, and each tenth into five parts; and then the vernier divides each of these fiftieths into twenty parts, giving the inch divided to thousandths.

The lower slide being brought to form a tangent to the mercury at the bottom, and the upper slide to be tangent to the mercury at the top, the two readings of the verniers are taken, and the difference is the altitude of the mercurial column.

There is only one thermometer supposed to be used with this barometer, and it is so attached as to show at once the temperature of the mercurial column and temperature of the air. The instrument should stand ten minutes or more before the observations be taken, in order that it may acquire the temperature of the air; and it should as much as possible be shaded from the sun. But as temperature is a main point both as regards the mercury and the air, it is desirable that a second thermometer be used as a check on the other.

It may once for all be remarked, that the term "attached thermometer," means temperature of the mercury, and "detached thermometer," means temperature of the air.

But as it is impossible to use this, or any other kind of mountain barometer, with any chance of success, without a stand of sufficient height to enable the eye to be brought on a level with the top and bottom readings of the mercury, I will briefly describe the very light and portable stand I contrived in 1837. This stand is a tripod of stout wire, about 1-5th inch in diameter, united by loops at the apex, each leg being 6 ft. 5 in. in length, with a socket joint in the middle; and at the apex is a hook on which to suspend the barometer. The lower part of each leg tapers a little. When the lower parts of the legs are withdrawn from their sockets, the stand packs in one-half of the leather case, and the barometer occupies the other half. The total height of the case is 3 ft. 4 in.; and it is provided with a strap and buckle to enable it to be slung across the back of an attendant; but it may be very conveniently carried in the hand.

When suspended on this stand, the lower slide of the barometer is about thirty inches from the ground, rendering it necessary to go on one knee to set the slide and to read the vernier.

If the wind is high, the oscillation of the barometer is so great that no observation can be taken. Should this be the case, tie a string to the bottom of the instrument, having a loop just above the ground; and if the end of the case be passed through this loop, and the case set in the direction of the wind, the barometer will be so firmly anchored to the ground, that it is held quite steady. Of course this should be done during a momentary lull of the wind when the barometer is perpendicular.

The eye or ring at the top of the barometer should turn freely, so as to give the means of turning the slides against the best light.

When the Gay-Lussac barometer is used, the only instrumental correction that is necessary is that for the temperature of the mercury, as in any set of observations the temperatures will generally be found to vary several degrees; and before these observations are used they must all be reduced to the lowest of the temperatures that occurred, as described in the second paragraph of the rule. Thus, suppose one observation to be 29·85 at 59°, and the other at 50°, the first must be reduced to 50°, by multiplying it by 9 and dividing the product by 10,000, giving ·027 to be deducted from it; so that 29·823 is the first observation at 50°.

To illustrate the application of the table and rule, when a mercurial barometer is employed, perhaps the following example may be given, taken from a book of tables lately published by the Indian Government.

M. Von Humboldt made the following observations to determine the height of the mountain Guanaxuato, in Mexico, in latitude 21°.

	Lower.	Upper.
Barometer . . .	30·045	23·659
Attached Ther. . .	77°·54	70°·34
Detached Ther. . .	77°·54	70°·34

Altitude according to	Oltmann	6838·3	Feet."
	Annuaire	6838·4	
	Baily	6838·9	

Now, here is as fair a test as could be found, by which to try the powers of the present approximate table in an extreme case.

Lower. . .	30·045	77°·54	B . .	1023·5
Mercury 7° .	·021	70·34		47·9
Lower corrected	30·024	147·88	B′ . .	1071·4
Upper . .	23·659	100·00		6·365
	2) 53·683	47·88		6819·5
			Lat.	13·7
Half sum . .	26·841			
				6833·2 Alt.
Difference. .	6·365			

Of course it is understood that M. Von Humboldt contrived in some way to secure that these observations at the top and bottom of the mountain should be simultaneous, as the atmosphere seldom remains an hour in the same state of temperature and pressure. It may also be remarked that it can in no way be accounted for that M. Von Humboldt should have entered the degrees of temperature to hundredths of a degree Fahrenheit, except by supposing that he used either the Centigrade or Reaumur scale, which would admit of degrees being read to tenths, and that some person, in turning these into terms of the Fahrenheit scale, put down the decimals just as they came out.

There is one more point that remains to be explained.

When two persons agree to observe according to time, one at the home datum station, while the other observes in the field, the first thing to be done is to compare the instruments, and note the difference as an index error, which must be applied, according to its sign, to the observations at the datum station.

Aneroids, by means of the screw, may be made to read together; but, as a rule, it is better to let the adjustment of instruments alone, and to apply such corrections as may be necessary. There is yet another way which does not require the index error to be known, which is by taking the changes at the datum station at the times answering to the field observations, and applying them as corrections to the lower, or first datum observation, in the field-book.

It may give facility to remark, that aneroids and Gay-Lussac barometers, with stands complete, are made according to the foregoing descriptions, by Messrs. Elliott Brothers, 30, Strand; not, however, with any advantage to myself.

War Office, January 1, 1859. S. B. H.

W. P. JACKSON, PRINTER, WOOLWICH.