R·E

PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

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PREFACE.

The contents of the present Volume will, it is hoped, not be found devoid of interest. Papers Nos. II., XI., and XIII., bear upon subjects connected with the War of 1870-1. Paper No. VI., by Baron Von Scholl, (translated by Lieutenant Anstey, R.E.), treats of proposed improvements in the form of Mining Galleries, &c. The Shoeburyness Experiments, up to a recent date, will be found recorded by Colonel Inglis, in Paper XVI.

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

Railway Department,
Board of Trade, Whitehall,
April, 1873.

LIST OF PLATES.

ERRATA.

In Page 18, line 3, for "Daujontin" read "Danjontin."

In Page 22, line 27, for "Munden" read "Meudon."

ERRATUM IN INDEX.

At Page 25, line 1, third column, for "VI." read "IV."

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PROFESSIONAL PAPERS.

PAPER I.

NOTES ON THE SUPPLY, STORAGE, AND TESTING OF PORTLAND CEMENT.

By CAPTAIN W. INNES, R.E.

The writer of the following paper was employed for some time on works where Portland cement was used in considerable quantities, and it occurred to him that the memoranda he had collected on the supply and storage of this material might, if thrown into a connected form, be useful to some of his brother officers.

Those desirous of fuller information on the subject should consult two papers by Mr. Grant, C.E., printed in the Minutes of Proceedings of the Institution of Civil Engineers, Vols. XXV. and XXXII.; there are extracts from them in the present paper, as well as some notes of the practice of other engineers, for which the writer is indebted to several members of the Institution of Civil Engineers, and to his own brother officers. What follows, applies more especially to the purchase of cement for use in day-work, but the essentials would be the same for its use by a contractor.

Delivery and storage.

When possible, Portland cement should be got direct from the manufacturer, who usually sells it by weight, the price being quoted at per ton, exclusive of packages, which are charged extra, and allowed for on return. The contractor's price may, or may not, include carriage to the wharf or railway station nearest the works; it is best that it should do so, that he may be entirely responsible for the condition of the cement on delivery. Wharfage, cranage, and local transport to the works are usually found by the purchaser. Where sea transport is available, quantities not less than the cargo of a vessel, can be supplied much cheaper than smaller amounts; and it will be worth while to have two prices, one for large orders equal to a cargo or more, and one for small ones. Ample time for delivery should be allowed in each order; to avoid misunderstandings it is best to insert a reasonable minimum, (varying from one to three weeks in the south of England, according to the situation and the means of transport available) in the contract.

Most manufacturers will supply cement either in casks holding between three and four cwt., or sacks holding two cwt. each, and it is best to have prices for both. Sacks are rather cheaper, though there is not much difference supposing the package in each case to be returned and allowed for; but, except for very small quantities on long journeys with much handling and exposure, sacks are the best, being a more convenient size and more easily disposed of when empty. The casks usually supplied will stand a shower of rain a little better than sacks, but have no pretensions to be air-tight, and are cumbersome and troublesome to dispose of when empty. The contract should provide for delivery in "sound" packages, but "air-tight" casks should not be specified unless specially required, as in case of exportation. Arrangements should be made to avoid exposing the cement on wharves or elsewhere in the course of delivery more than is absolutely necessary, and sufficient tarpaulins to cover the largest quantity likely to be so exposed at one time should be ready in case of rain.

Sheds or other buildings for storing cement should be perfectly dry and weather-tight, with floors raised above the ground. The accommodation should be at least sufficient for the consumption during a time three weeks or a month longer than that allowed for the delivery of an order, so as to provide for replacing any cement failing to pass the tests (which, with storing, may be reckoned to require ten days), without incommoding the works, and should be so arranged as to admit of storing each delivery separate. It is a good plan to empty the packages and store the cement in bulk; it keeps better, the quality is made more uniform, and the quantity of casks or sacks on hand is reduced to a minimum. Good cement, properly housed, can be stored six months without material injury.*

Essentials of good cement. The qualities essential in Portland cement are high and uniform strength, capacity for sand, and stability; great quickness of set is not commonly looked for, other cements being used when this is required.

Strength. The strength is tested directly, and may also be inferred to some extent from the weight and appearance. The direct strength test usually consists in breaking specimens gauged net, and kept seven days in water, (a longer time with a suitable increase in the strength required is better if it can be conveniently allowed) by tension, the cement being moulded into briquettes of the shape of two blocks about 3 in. by 3 in. by 1½ in., joined by a neck, 1½ in by 1½ in., and giving a consequent sectional area for breaking of 2¼ square inches. Good cement so treated will show a breaking strength of from 600 lbs. to 900 lbs. on this section, or about 270 lbs. to 400 lbs. per square inch. It is

* It will, however, lose its *rapidity* of set to a considerable extent; some kept six months in store at Portland fell from an average of 800 lbs. to 587 lbs. per briquette of 2¼ in. section, at *seven* days, but the store was not a very dry one, and the cement was stowed in the sacks instead of in bulk.

safe to specify an average of 350 lbs., and a minimum of 225 lbs., per square inch, such cement being readily obtainable in the market. It is better to do this than to specify a minimum only, as is commonly done, such a test will be either too low or too severe to enforce in practice. The weight of cement is a pretty good indication of its strength, the heaviest cement being, *ceteris paribus*, the best; it is particularly valuable as an index to the greatest *ultimate* strength likely to be attained as distinguished from that at the short dates which only can be allowed for testing; that is to say, that a heavy cement will probably go on hardening longer, and be eventually stronger, than a light one having the same strength at seven days. Good cement, as sold generally, weighs from 110 lbs. to 125 lbs. per bushel; but the higher weights are often due to coarse grinding, and to give this test a uniform meaning, it is best, though not usual, to apply the weight test to a sifted sample*; 108 lbs. per bushel will be a high enough minimum for cement which has passed a sieve of 2,500 meshes per square inch. The best cement presents a dark, compact, splintering fracture; weak cement, a rotten, clayey-looking one.

Rapidity of set.

For some purposes it may be necessary to ensure a higher degree of activity than is indicated by the seven days' test alone; this can be done by the additional strength tests at shorter dates, which will be found in some of the specifications. The test of activity used for quick setting cements in the United States, which consists in subjecting a cake of cement to the pressure of the end of a loaded wire of known weight and diameter, which must be carried without indenting the surface within a fixed time of gauging, would also answer the purpose, but has never been used for Portland cement in this country; further particulars of this mode of testing may be found in General Gilmore's book on Limes and Cements. No test of this kind is usually necessary, it being sufficient if the briquettes will bear removal from the moulds within a reasonable time, say twenty-four hours.

Capacity for sand.

Capacity for sand does not always go along with strength, that is to say, the stronger of two cements, gauged net, may give the weaker mortar when mixed with sand, or, at least, lose much of its apparent advantage.† It depends, other things being equal, on the fineness of the powder to which the cement is reduced; and specifications usually provide that the cement shall be "ground extremely fine," but the point has not hitherto received very much attention, and it can hardly be said that any definite standard of fineness is recognized in the trade at present (1871). There is, however, reason to think that cement has become coarser as greater weight has been insisted on, the dense highly calcined particles being very hard to pulverize, and it is very necessary to have some exact test of fineness annexed to the provision for a high weight. One-fiftieth of an inch square (2,500 per square inch) is as fine a mesh as can be conveniently used in practice, smaller ones clogging very easily; on the other hand, cement reduced to this fineness has a very appreciable superiority

* In the Specifications which follow, the weight test was for unsifted cement.

† If properly ground, however, the strongest cement would, probably, always maintain its place.

with sand as compared with even slightly coarser samples; and a mesh of this size would be a very good standard, but that no heavy cement is made up to it at present. In the writer's opinion, it would be best to adhere to it, notwithstanding; not rejecting deliveries which are too coarse, but ascertaining and deducting from the amount to be paid for the per centage which fails to pass the specified mesh. Such a condition would soon be understood; the price of the cement, though nominally higher, would remain really unaltered, the manufacturer allowing for the probable deduction and no more, in his price, whilst it would offer a strong inducement to him to grind the cement as fine as he profitably could. If this plan be objected to, the specification may provide either that the whole of the cement shall pass a coarser mesh, or that a certain per centage shall pass the $\frac{1}{50}$-in mesh. Cement of good weight can now be had to pass nearly all through a sieve of 900 meshes, or 85 per cent. through one of 2,500 meshes per inch.

The breaking tests at short dates (see specifications, pages 10, 12, and 13), which some engineers enforce in addition to that at the usual period of seven days, replace a fineness test to some extent, coarse cement setting slower than fine, otherwise of the same quality; great ultimate strength after VERY slow setting may be obtained from good cement insufficiently ground, which would give bad results with sand. This is, however, hardly so convenient or reliable a test as sifting.

When work is being done by contract, the contractor finding his own cement, the penalty for coarseness must be varied, as in such a case, it cannot properly be applied in the form of a pecuniary deduction for any undue proportion of coarse grains; it will probably be best to provide, that cement not up to the specified standard of fineness, shall be either rejected, or used with a smaller proportion of sand, at the discretion of the Superintending Officer, and to put the standard at what may be readily got in the market. A direct test of the strength of samples, gauged with the sand actually employed by the contractor on the works, would be very satisfactory, and might be adopted in some cases, but would be inapplicable in the majority, because the setting is so much retarded by an admixture of sand that the time required for setting in order to get a trustworthy result is inconveniently lengthened.

A direct test of capacity for sand is inapplicable to cement purchased from the maker, both for the above reason and also because the kind of sand used affects the result, so that in case of a failure the question would be raised whether it was due to the sand or the cement.

Stability. By stability is meant freedom from any alteration of form after beginning to set. The commonest defect in this respect is a tendency to swell and break up, usually termed "blowing," due to over-limed or under-burned cement; shrinkage, due to excess of clay is much rarer, and over-clayed cement betrays itself by its bad colour, weakness, and low weight. Stability is tested by carefully watching small samples gauged net and kept in air and water, the latter being the more important. Those inclined to blow show signs of expansion when kept a day or two in water; in extreme cases, the sample will entirely break up, but a few fine cracks about the edges are the commonest indications. It is usual to make pats, about 3 in. in diameter and half an inch thick, for the water-test, as this is called; but when the ordinary briquettes for the strength test are made, they show any tendency to blow as well or better, and the pats are unnecessary, unless, as is sometimes done, one is kept in air as an additional precaution. In cases where there is any doubt, changes of form may be noted with great accuracy in a sample allowed to set in a phial or gallipot, which will be cracked by any expansion; but the extra time and trouble required for this are not worth incurring, save on special occasions. Cement with any tendency to blow is a very dangerous material, and should never be used. Most heavy cement does it *slightly* when freshly made,* but becomes safe after a short exposure to the air in thin layers, without deteriorating perceptibly in other respects, *if of good quality*; but this exposure is best made by the manufacturer before packing, and the specification should provide for the cement being delivered fit for use, otherwise one's storage accommodation may be crowded with useless, or, at least, unavailable material at some critical period of a work, besides the risk of loss of strength in cooling (as the change in cement by exposure is termed), the cause of which, as to whether arising from bad cement or defects of storage, will always be matter for dispute. In testing for stability, *fresh* samples must be used; cement which has been a day or two in the small sample bags will have cooled so as to set properly.

Chemical analysis.

When the cement is tested carefully on the foregoing points, a chemical analysis will hardly be required; but if a competent analyst is available, it is an advantage to have a sample chemically tested occasionally, particularly in cases of any peculiarity of behaviour under the ordinary tests, or where there is reason to suspect adulteration.

Practice of testing at Portland.

The following is an outline of the manner in which the cement was actually tested at Portland, when there were about two deliveries a month, of some 80 tons each.

The cement was sea-borne, and delivered in sacks at a wharf near the store. The testing-machine, though in a separate room, was under the same roof; this proved a bad arrangement, as the fine dust arising from handling the cement penetrated everywhere, and was continually clogging the working parts of the machine, (though it was carefully covered when not in use,) so that perpetual cleaning was required to keep it in working order.

The following is a list of the tools and appliances which were used, viz.:—

- 1 Testing machine.
- 1 Moulding press.
- 1 Pair of iron clips.
- 100 Iron moulding plates for briquettes.
- 100 Ditto ditto pats.
- 6 Gun-metal moulds.
- 100 Canvass sample bags, 12 in. by 6 in., numbered consecutively in inch figures.
- 1 Brass sieve of 2,500 meshes per square inch, and about 12 in. diameter.
- 1 Weighing-machine, ¼lb. to 5 cwt.
- 1 Bushel measure.

* Cement in this state often heats perceptibly on being mixed with water.

1 Wooden straight-edge, 3 ft.
1 Short piece of wood spouting.
1 Trowel.
1 Mortar board.
1 Pair of gloves.
1 Shovel.
2 Rough wood boxes, about 2 ft. by 2 ft. 6 in. by 1 ft. for sifting into.
12 Tanks, wooden.
2 Water pails.
1 Half-round rasp, for trimming briquettes which had lost their shape.

Adie's Cement Testing Machine.

(From Mr. Grant's Paper).

The testing machine used, was made by Mr. Adie, of Pall Mall, and was of the same pattern as those supplied by him to the Metropolitan Board of Works, consisting of a steel lever with a travelling weight on the long arm, the knife edge on which the lever turned being supported on a short cast-iron column mounted on a wooden frame. (Fig. 1.)

The briquette under trial, of the form shown in Figs. 2 and 3, was placed in a pair of loose fitting iron clips, which were then connected, one to the short arm of the lever, and the other to the frame; the frame connection could be adjusted by means of a screw and hand-wheel until the briquette took the strain applied through the lever by the travelling weight, the amount of it for each position of the latter being shown by a scale engraved on the long arm. With the machine in its ordinary adjustment, the force exerted varied from 300 lbs. to 1,100 lbs., but its range could be extended either by an extra weight on the end of the long arm which increased every reading by 800 lbs., or by a counterweight in the same position which diminished each 300 lbs., so as to give a total range of from 0 to 1,900.

Michele's Cement Testing Machine.

Another instrument has been lately patented which promises well, but the writer has had no opportunity of trying it. (See Figs. 4 and 5, and description below.) It is cheaper than Adie's, and is now under the consideration of the Royal Engineer Committee.

The block to be tested is placed in the jaws prepared to receive it; the hand-wheel is then turned, which raises the weighted lever by exerting a pull on its short end through the medium of the cement block. When the leverage is so increased as to exert a force too great for the cement to sustain, it breaks, and the lever falls, leaving the index-pointer at the spot to which it had been raised. The arc along which the pointer moves is graduated to show the number of pounds of tensile strain applied. A suitable arrangement, when the cement block breaks, prevents the lever from falling more than half an inch.

Moulding Press.

(From Mr. Grant's Paper.)

The moulding press consists of a rim made to fit the outside edge of the gun-metal moulds, and suspended by a vertical rod to a pair of C springs over a cast-iron block of the size and shape of a briquette, down on which it can be forced by a lever working against the top of the suspending rod; the whole affair is mounted on a cast-iron pedestal.

The clips were made of a shape and size to fit loosely over each half of a briquette (see dotted lines on Fig. 2,) and had a projecting eye on one end of each for the pin to connect with the testing machine.

The briquette moulding plates were of sheet iron, about ·1 in. thick, cut to the shape of a briquette in plan, but a trifle smaller, so as to pass readily through the moulds; those for pats were 3½ in. square.

The moulds were stout gun-metal castings made like a brick mould, without either top or bottom, and having the interior of the exact form and dimensions of a briquette, save a slight excess of depth to allow for the thickness of the moulding plates.

The tanks were 3 ft. by 1 ft. 9 in. by 3 in., and held twenty briquettes each. They were made of yellow deal, put together with white lead, and well coated with tar and pitch They might have been two or three inches narrower with advantage.

The gloves were stout leather ones, such as are used by hedgers, and were required to protect the moulder's hands, which otherwise soon became sore.

The whole of the foregoing apparatus is not absolutely necessary, but it would be very difficult and tedious to conduct operations of any extent without all or most of it.

Where a testing machine is not available, and the briquettes have to be broken by hanging the weight directly from them, it will be found best to apply about three-fourths of the anticipated breaking weight with iron or other weights of the largest size convenient for handling, and to add the remainder by means of a chain lowered into the scale link by link, or by dry sand poured into a basin placed in it.

Wooden moulds to contain six or eight briquettes each, and made to take to pieces after they have set, may be substituted for the metal moulds and press in case of necessity.

The storeman who received the cement opened every twentieth sack, and put aside a sample from it (*i.e.*, one sample per ton) for testing, in one of the small numbered bags; every tenth sack of those opened (being one in two hundred of the entire cargo) was weighed, first full and then empty, so as to get an average weight per sack, to check the total amount of the delivery; a bushel from each of these last was measured and weighed, the cement being slid gently into the measure down a short piece of wood trough or spout, stirred just sufficiently to fill the corners, and struck off with a straight edge.*

* This operation required to be very carefully conducted, as the cement was very easily consolidated, so as to weigh heavy; the results got by weighing on a timber jetty, which was trembling slightly from some wharfage operations, were several pounds higher than those given by the same cement weighed on firm ground.

(The plan used by Mr. Grant, C.E., in his last experiments, seems better calculated to ensure uniformity; he filled the cement from a hopper at a uniform height of two feet above the mouth of the measure.)

The moulding was begun as early as convenient after the samples were taken; generally the next day. The briquettes were made separately, one from the contents of each sample bag, the mortar being gauged stiff with the smallest possible quantity of water (one measure of water was enough for about three and a half of cement), and filled into a mould placed on a firm even level surface with a moulding plate laid in the bottom; a short stick, about half an inch square was used for packing the mortar into the corners, and particular care was taken to fill the neck solidly; when the mould was full, the mortar was struck off level with the trowel, and the number of the sample scratched upon it. If a pat was required, it was made from what remained of the mortar, placed on one of the square plates, and marked with the same number as the briquette from the same sample. The mortar board was then cleaned, and the next sample gone on with. By the time six briquettes were moulded, the first made was generally sufficiently set to bear removal from the mould; this was done by placing it on the block of the press and depressing the handle of the lever, so as to thrust the mould off it, and down over the block, leaving the briquette and moulding plate resting upon it. The briquette, still on the plate, was then lifted off and placed in a tank, which was filled up with water within an hour or two of receiving the last briquette.* The moulding being completed, the cement left in the sample bags was emptied in a heap on a clean floor and well turned over. Twenty-five pounds of the mixed samples was then sifted, and the quantity passed and rejected by the sieve noted, each quarter of a pound representing one per cent.

After being kept seven days in water, during which period they were examined for symptoms of blowing, the briquettes were knocked off the moulding plates (which were kept greased to prevent adhesion), trimmed, if necessary, with the rasp to fit the clips, and broken down in the testing machine. In doing this the weight was run out steadily and pretty quickly along the arm, whilst an assistant kept the strain on the specimen by tightening the hand-wheel, if necessary; if it did not break with the weight at the end of the arm, the former was run back to the zero of the scale, and the hand-wheel slackened till the end of the arm rested on its bearing; the extra weight was then applied, the hand-wheel tightened again, and the operation repeated.

The various particulars and results of the foregoing were noted, as observed, in a register kept in the annexed form, and a decision was come to as to whether the delivery should be received, and what should be the exact amount credited to the contractor.

* Care should be taken not to remove the briquettes from the moulds too soon, or they will lose their shape, and be troublesome to fit in the clips of the testing machine.

Form of Register used at Portland.

__ th Cargo, received per _______________, on_______________.

No.	Dates of			Age.			Weight.			Tested by.		Remarks.
	Moulding.	Immersion.	Breaking.	In air.	In water.	Total.	Per sack.	Per bushel.	Breaking.	Moulded.	Broken.	
2125	14-8-69	15-8-69	22-8-69	1	7	8			670			* (Including sack and measure).
2126	,,	,,	,,	,,	,,	,,			621			Any peculiarities of individual specimens such as distortion requiring trimming with rasp, flaws in neck seen in fracture, &c., noted here; also any appearance of blowing.
2127	,,	,,	,,	,,	,,	,,	228*	150·5*	640			The results of the sifting were noted at the end of the set of tests for each cargo.
2128	,,	,,	,,	,,	,,	,,			627			
2129	,,	,,	,,	,,	,,	,,			498			
2130	,,	,,	,,	,,	,,	,,			600			

The following extracts from specifications and summaries of the results of testing are intended to give a general idea of the actual cotemporary practice on works of importance.

*Portland Defences.**

"The cement to be of the best quality, ground extremely fine, and quite free "from coarse inert particles; to weigh not less than 108 lbs. per striked bushel "(filled into the measure as lightly as possible), to have a breaking weight of not "less than 250 lbs. per square inch of section, when made into moulds and sub-"jected to tension after seven days' immersion in water; to show no signs of "cracking, swelling, or shrinking, when made into cakes half an inch thick, "after any length of immersion."

* Obtained from Lieutenant E. M. Lloyd, R.E.

Abstract of the Results of the Tests of the several Cargoes of Cement supplied for the Breakwater Fort, Portland.

Cargo. No.	Cargo. Quantity.	Date of breaking.	No. of test briquettes.	Weight per bushel. As received.	Per centage of coarse particles.	Breaking weight (on $1\frac{1}{2}$ in. by $1\frac{1}{2}$ in.)	Remarks.
	tons.			lbs.		lbs.	
1	81	26 Sept., '68	40	114·7	—	824	Hardly a *single* test below the specified strength in the whole of these cargoes.
2	80	17 Oct., '68	40	121	31	915	
3	80	21 Nov., 68	40	123·8	30·5	855	
4	81	8 April, '69	40	118	31	808	
5	80	22 April, '69	40	116	32·2	827	
6	80	9 June, '69	40	124·5	27	825	
7	80	19 June, '69	40	121·9	33	755	Rejected for showing a tendency to swell and break up in water, and having some strength tests below the minimum specified.
8	80	10 July, '69	40	118	27	749	
9	80	28 July, '69	40	119·4	27	796	
10	80	6 Aug., '69	40	118·3	29	869	
11	80	18 Aug., '69	40	116	32	860	
12	80	24 Aug., '69	40	117	31	829	
13	80	28 Aug., '69	40	117	32	925	
14	80	4 July, '70	40	120·2	28	549	Gave a rather better result (viz., 628 lbs.) after being kept a month; was evidently too fresh, and wanted cooling.
15	80	3 Oct., '70	40	116·7	20·5	800	
16	80	——	—	—	—	—	This was not tested till we had had it some months, on account of frost. It was then tried three times, giving very irregular results, but all very bad. It was rejected.
17	80	13 April, '71	40	121	20	720	
18	80	25 Sept., '71	40	118·5	24	890	

*Sir John Coode's Works—chiefly Harbour.**

"The cement supplied must be uniformly burnt, and finely ground, and weigh "*at least* 112 lbs. per bushel; sample test-bricks, having a minimum section of "$1\frac{1}{2}$ in. by $1\frac{1}{2}$ in., must be made from the bulk of the cement before the ship-"ment of each cargo. They must be placed under water immediately after "setting, and bear *at least* the following tensile strains:—

"48 hours after gauging, 350 lbs. per block.
4 days " " 500 lbs. "
7 days " " 750 lbs. " "

* Obtained from Sir John Coode, Memb. Inst. C.E.

For a long time past the cement supplied under the foregoing clause has exceeded 850 lbs. at the end of seven days, and for the last twelve months or so, from 1,000 lbs to 1,200 lbs. on the same section, and at the same age. No particular standard of fineness was considered necessary.

*Dover Harbour Works.**

"The Portland cement is to be of the very best manufacture, not less than "120 lbs. to the striked bushel, lightly filled, to be ground to a fine powder, "and free from core and foreign matter, and to be approved in all respects by "the Engineer."

The following is the standard of strength expected by the Engineer, and which is usually exceeded in practice: —

At 48	hours,	130 lbs.	per square inch
At 72	„	175 lbs.	„
At 96	„	200 lbs.	„
At 168	„	225 lbs.	„

Each weight being an average of ten experiments, and obtained from a section of $6\frac{1}{4}$ *square inches* (= $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in.)

The cement is expected to pass a $\frac{1}{20}$-in. mesh sieve (400 holes per square inch)."

Tyne Pier Works.†

"To be equal in quality to the best manufactured near the Thames."

The Portland cement actually used on the Tyne works weighs over 120 lbs. per bushel, lightly filled; and the test bricks made with breaking section of two inches super., generally require a breaking strain of 5 cwt. (equal to 280 lbs. per square inch) after having been mixed and immersed for seven days.

Metropolitan Main Drainage and Thames Embankment.

(Extracted from Mr. Grant's paper in Vol. XXXII. of the Minutes of Proceedings of the Institution of Civil Engineers.)

"The whole of the cement shall be Portland, of the very best quality, ground "extremely fine, weighing not less than 112 lbs. to the striked bushel, and "capable of maintaining a breaking weight of 350 lbs. per square inch seven "days after being made in a mould, and immersed in water during the interval "of seven days. The Contractor shall at all times keep upon the works a sup- "ply of cement equal to at least fourteen days' requirements; and with each "delivery of cement shall send to the Clerk of Works a memorandum of the "number of bushels sent in, and the name of the manufacturer."‡

* Obtained from E. Druce, Esq., Memb. Inst. C.E.

† Obtained from P. Messent, Esq., Memb. Inst. C.E.

‡ These works were within easy inland water carriage of the principal seat of the cement manufacture, so that cement could be brought from one to the other by barge.

The annexed tables show the results of the testing, and the gradual increase of the standard of strength exacted on these works.

Particulars of Portland Cement supplied during the last 5 Years, with average Breaking Weight at 7 Days on 2·25 Square Inches.

Names of Manufacturers and Agents.	Quantity in Bushels.	Average weight per bushel.	Number of tests.	Average breaking weight.
Townly	31581	118·27	550	862·01
Booth	12464	119·75	80	846·50
Lee & Co.	512	120·00	10	839·00
Burham Brick and Cement Company	320716	113·54	3705	825·73
Casson & Co.: Agents	5200	114·50	50	816·80
Knight, Bevan, & Sturge	19429	114·52	820	803·38
Robins & Co. (Limited)	68880	118·00	620	795·31
White & Co.	60	119·00	10	791·70
Burge & Co.: Agents	4500	113·00	30	789·30
Hilton	103453	117·17	1300	786·99
Beaumont: Agent	40	116·00	10	765·00
Lavers: Agent	12002	116·17	160	706·97
Weston	600	120·00	10	666·40
Young & Son: Agents	200	117·00	10	655·80
Coles & Shadbolt	240	107·00	10	580·00
Tingey	6300	115·50	100	564·27
Harwood & Hatcher: Agents	3040	117·78	30	408·03
Generally	589217	115·23	7505	806·63

Specified Standard of Portland Cement supplied by Manufacturers.

	Breaking weights.	
	At per square inch.	On $2\frac{1}{4}$ square inches.
	lbs.	lbs.
Greenwich and Deptford Sewers	222·2	500
Woolwich Sewers	250	562·5
White Post Lane	„	„
The Earl, Battle Bridge, &c. ...	„	„
Falcon Brook	„	„
Heath Wall	„	„
Southern Thames Embankment	„	„
Southwark Park	350	787·5
Bankside	„	„
Bermondsey Street, &c.	„	„
Belvedere Road, &c.	„	„
Plough Road	„	„
Putney Boundary	„	„
Kennington Park Road	„	„
Kennington and Lambeth	„	„

*Aberdeen Harbour Works.**

"The Portland cement to be of the best quality, and in every way suited for "the pier and harbour work, to be finely ground, and to weigh not less than "115 lbs. per striked bushel, Imperial measure.

"Sample blocks to be made out of each delivery of cement in a metal mould "having a minimum area of $2\frac{1}{4}$ square inches, these blocks to be immersed in "water immediately after setting, and must bear the following tensile strains :—

"48 hours after gauging, 300 lbs. per block.
4 days after gauging, 450 lbs. „
7 days after gauging, 600 lbs. „

"The tests to be in all respects subject to the approval of the Engineer to the "Commissioners."

The annexed table shows the results of the testing under the above specification.

* Obtained from W. Dyce Cay, Esq., Ass. Inst., C.E.

Aberdeen Harbour.

New South Breakwater Works. – Table showing Strength of Portland Cement.

No. of Cargo.	Weight per bushel.	Average of 10 highest 7 days' test.	Average of 10 lowest 7 days' test.	Average of 20 tests, viz., 10 lowest and 10 highest.	Per centage of residue sifted through sieve 900 holes per sq. inch.	No. of test blocks hacked.	No. of 7 days' test blocks made.	Invoiced weight of each cargo.			REMARKS.
								Tons	cwt.	qrs.	
1	114	...	...	...	...	...	15	120	0	0	
2	130	875·8	676·6	776·2	...	...	24	132	0	0	
3	124	1032 3	...	...	...	...	14	130	0	0	
4	124	988·2	...	...	...	...	13	110	0	0	
5	122	870·3	...	...	...	7	11	70	0	0	
6	119	735·8	...	...	...	13	16	110	0	0	
7	123½	699·3	620·5	659·9	..	...	23	85	0	0	
8	122¾	819·8	616·8	718·3	...	...	36	107	0	0	
9	120¾	769·8	580·5	675·1	...	9	24	93	0	0	
10	116	681·6	490·6	588·1	5½	...	21	96	0	0	
11	126¾	741·1	659·4	700·2	6	...	20	144	11	2	
12	127¾	801·0	611·6	706·3	8½	...	23	129	14	0	
13	115¼	834·5	505·8	669·9	14	1	29	67	15	0	
14	114	625·5	432·0	523·7	13	6	28	90	0	0	Rejected.
15	127	779·0	618·5	698·7	8	...	29	137	8	2	
16	113	601·8	425·5	513·6	16	2	47	90	0	0	Rejected.
17	117	950·2	724·0	837·1	10	...	30	139	7	3	
18	119½	955·7	688·5	812·1	11¾	2	27	129	9	0	
19	....	....	....	Wrecked.	....	....	....	118	0	0	
20	115	863·3	394·5	628·9	11	50	198	109	7	0	
21	125¾	900·3	693·4	796·8	4½	...	20	138	16	0	
22	126	778·8	637·5	708·1	3	...	20	84	6	0	
23	124¾	771·4	557·6	664·1	3½	...	43	247	16	0	
24	119¾	875·4	487·7	681·1	4¼	...	40	196	6	0	
25	121¾	921·2	629·8	775·1	3½	4	40	133	18	0	
26	125½	928·7	642·2	785·4	4	...	40	208	4	0	
27	....	....	....	Wrecked.	....	....	....	123	18	0	
28	125½	918·4	675·8	797·1	3½	...	40	178	10	0	
29	123½	934·9	694·1	814·1	5½	...	40	148	14	0	
30	125	910·6	674·5	792·1	4½	...	40	178	10	0	
31	125½	960·2	685·5	821·1	4½	...	40	148	14	0	
32	125	921·8	667 0	794·4	4¼	...	40	183	8	0	
33	123½	866·0	570·5	718·2	3	...	40	208	4	0	
34	121	860·0	662·4	761·2	3½	...	40	138	16	0	
35	123	778·8	621·3	699·1	4½	3	40	148	14	0	
36	123½	771·4	452·9	612·1	4	1	90	148	14	0	

*Cork Harbour Defences.**

"The cement to be of the best quality of strongly burned English Portland, "ground fine enough for 80 per cent. to pass a sieve of 2,500 meshes per square "inch. The excess of 20 per cent. which will not pass the above mesh, to be "ascertained by sifting a mixed sample of not less than 25 lbs. taken from one-"tenth of the packages supplied, to be deducted from the gross amount to be "paid for.

"The cement to weigh not less than 110 lbs. per striked bushel when filled into "the measure as lightly as possible, by sliding down a piece of board or spouting.

"Briquettes of net cement, gauged as stiff as possible, and put in water "within 24 hours, to have a minimum tensile strength of 562½ lbs. to 2·25 "square inches of section after seven days' immersion. Tests from every tenth "package must give an average up to the above with not more than two per "cent. of the tests below the minimum.

* Obtained from Captain P. Maquay, R.E.

"Sample pats, about 3 in. in diameter by half an inch thick, gauged net and "kept dry, must set well without shrinking or change of colour or shape.

"Sample pats, as above, kept in water, must set well without cracking or "swelling. Tests from every tenth package must not give more than one per "cent. failures.

"The cement may be subject to a chemical analysis to ascertain its purity, "the proportion of its ingredients, and the absence of foreign matter."

The annexed table gives the results of the testing under the above.

NATIONAL DEFENCES, CORK HARBOUR.

CEMENT TESTING REGISTER.

No. of Tests.	Dates of			Age.			Weight in lbs.			Per centage of coarse.		REMARKS.
	Moulding.	Immersion.	Breaking.	Days in Air.	Days in water	Total.	Per sack.	Per bushel.	Breaking on 2·25 sq. ins.	1,600 meshes per inch.	2,500 meshes per inch.	
10	10 Nov., '70	10 Nov., '70	17 Nov., '70	Nil.	7	7	251	112	886	6	9	
18	11 Nov., '70	11 Dec., '70	19 Dec., '70	30	7	37	251	112	1065	6	9	
6	14 Nov., '70	15 Nov., '70	22 Nov., '70	1	7	8	251	112	815	6	11	
4	12 Nov., '70	12 Nov., '70	19 Nov., '70	Nil.	7	7	251	112	863	6	10	
4	12 Nov., '70	12 Nov., '70	19 Nov., '70	Nil.	7	7	251	112	772	6	10	
10	15 Nov., '70	15 Nov., '70	22 Nov., '70	Nil.	7	7	412 (cask)	104	651	13	19	Supplied by triennial contractor.
14	16 Nov., '70	16 Nov., '70	23 Nov., '70	Nil.	7	7	251	112	803	6	11	
12	17 Nov., '70	17 Nov., '70	24 Nov., '70	Nil.	7	7	420 (cask)	112	737	14	19	Supplied by triennial contractor.
21	17 Nov., '70	17 Nov., '70	15 Dec., '70	Nil.	29	29	251	112	1039	..	..	
12	12 Dec., '70	12 Dec., '70	19 Dec., '70	Nil.	7	7	253	113	770	16	20	
8	14 Dec., '70	14 Dec., '70	21 Dec., '70	Nil.	7	7	253	113	956	15	20	
26	9 Jan., '71	9 Jan., '71	16 Jan., '71	Nil.	7	7	253	113	707	15	20	Cargo partly damaged by sea.
10	21 Dec., '70	21 Dec., '70	19 Jan., '71	Nil.	29	29	253	113	836	15	20	
20	18 Jan., '71	18 Jan., '71	25 Jan., '71	Nil.	7	7	251	113	885	6	7	
23	10 & 11 July, '71	10 & 11 July, '71	17 & 18 July, '71	Nil.	7	7	253	113	812·95	17	20	
30	8 Aug., 71	8 Aug., '71	15 Aug., '71	Nil.	7	7	254	114	915·5	..	23	A deduction made for coarse cement.
26	16 & 17 Aug., '71	16 & 17 Aug., '71	23 & 24 Aug., '71	Nil.	7	7	252	115	764·61	..	23	A deduction made for coarse cement.
30	20 Sept., '71	20 Sept., '71	27 Sept., '71	Nil.	7	7	250·5	116	808·1	..	18	
30	23 Oct., '71	23 Oct., '71	30 Oct., '71	Nil.	7	7	253	116	806·66	..	15	
30	16 Nov., '71	16 Nov., '71	23 Nov., '71	Nil.	7	7	250	112	841·2	..	12¼	

Suggested Specification.

The following are the testing clauses which the writer would suggest in a specification for the supply of Portland cement on important engineering work.

The cement to be the best Portland, of uniform quality, and free from foreign or inert matter of any kind; to weigh not less than 108 lbs. per striked bushel, when filled into the measure as lightly as possible, from a hopper eighteen inches above its mouth; and to be fine enough to pass a sieve of 2500 meshes per square inch, the proportion of any delivery failing to pass the special mesh to be deducted from the amount credited to the contractor, and the weight test in all cases to be applied to a sifted sample. When gauged net it must set either in air or water without any alteration of size or form, and blocks made of it and placed in water as soon as they will bear removal from the moulds (which must be within twenty-four hours), must give a minimum ultimate tensile strength of not less than 225 lbs., and an average of not less than 350 lbs., per square inch, after seven days immersion.

Interpretation of specification

In interpreting the above specification, any cracking or alteration of form while setting, or a deficiency of weight or average strength below the specified standards, should cause the rejection of the delivery. Not more than one or two per cent. of the strength tests should in any case fall below the minimum, and a single one falling below it should cause rejection if the quality of the cargo appears variable, and there are many single tests below the specified average. About one test per ton for strength and stability, and a single test of a mixture of samples, taken at the rate of one per ton for weight and fineness, will be a sufficient number.

Precautions in testing.

It must be borne in mind that cement will only give the high strengths specified under suitable and careful manipulation, and at ordinary temperatures. An intelligent labourer should be trained for the purpose (there is no difficulty in doing this), wherever any quantity of cement is received, and the tanks containing the briquettes should not be exposed to cold; in England, it is generally sufficient if they are indoors in a substantial building. Any briquette breaking low, should have the neck examined to see that it is of full section and without flaws.

Alternative specification.

If the weight and fineness clauses, as drawn in the foregoing be objected to as too great an innovation, they might stand as follows, viz:—"To weigh not less than 112 lbs., per striked bushel when filled into the measure as lightly as possible from a hopper eighteen inches above its mouth, and to pass a sieve of 900 meshes per square inch."

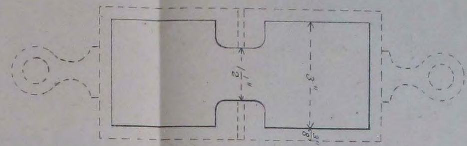
These requirements would almost certainly be met at once by some makers. And, again, where circumstances permit, the time for the strength test might be advantageously extended to thirty days, and the average and minimum strengths raised to, perhaps, 450 and 350 lbs. per square inch, respectively.

Hasty testing.

When time or appliances fail for testing in a regular manner, a tolerable judgment can be formed on the material by watching the behaviour of pats about 3 in. across by ½-in. thick, two of which should be made from each sample and kept under observation, one in air and one in water, as long as possible. The weight and fineness tests will almost always be available.

W. I.

FIG 2.



ADIE'S CEMENT TESTING MACHINE.

(From Mr. Grants paper.)

FIG 1.

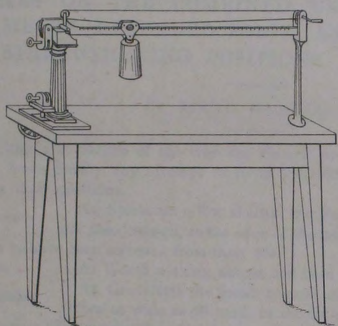
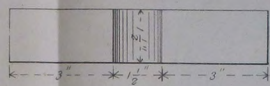


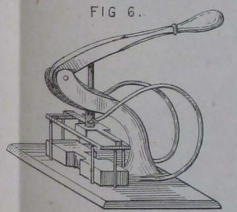
FIG 3.



MOULDING PRESS.

(From Mr. Grants paper.)

FIG 6.



MICHELE'S CEMENT TESTING MACHINE.

FIG 4.

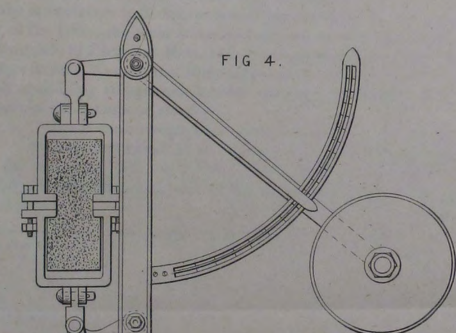
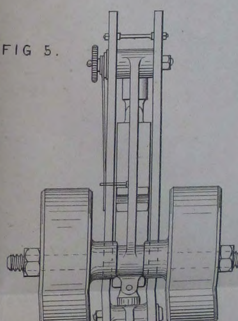


FIG 5.



PAPER II.

NOTES ON THE COMBINED USE OF ENTRENCHMENTS, DEFENDED POSTS, AND REDOUBTS, FOR STRENGTHENING POSITIONS. WAR OF 1870-71.*

By LIEUT. FRASER, R.E.

In the first battles of the war the French were so taken by surprise, that they made hardly any attempt to cover their inferiority in numbers by fortifying their positions.

Spicheren. At Spicheren a few shelter trenches had been made near, but not near enough, to the edge of the heights under which the attack seems to have been screened from their fire.

Worth. At Worth nothing almost had been done.

Gravelotte. At Gravelotte the great natural ditch in front of the position (often as wide as 60 yards at the bottom, and with banks at places as steep as 28°), rendered artificial preparations less necessary; and on the right, at St. Privat, the position had been slightly entrenched with good results, as the loss to the attack in moving up the long bare slope in its front convinced the Germans that advances under such circumstances must cease to be made, except in skirmishing order, or something approaching it.

Sédan. At Sédan, on the Flöeing side of their position, shelter trenches (section about 4 feet wide and 2 feet deep), were used on the plateau between the farm of La Garenne and Flöeing, where some very severe fighting seems to have taken place; but the whole position was so radically bad, that no amount of preparation could have changed the result.

After the capitulation at Sédan, and with the exception of the campaign of the army of the Loire, the main features of the war were the prosecution of the great investments of Paris and Metz, and the sieges of various places of greater or less importance. Most of the theatre embraced thickly inhabited districts with many close-lying villages and houses, and these frequently played an important part in the defence or attack.

Orleans. The French troops have always been quick at turning cover to account, and excellent use is said to have been made by their new levies of the numerous villages before Orleans, such as Coulmiers, Artenay, Bacon, and Poupry, &c., and also in the campaigns of Le Mans and those north of Paris.

* This Paper was written before the issue of the last volume of Corps Papers, but too late for insertion in that volume.

Belfort.

The protracted defence of Belfort, too, was due in great measure to the energy which the Engineer Commandant and the Garrison showed in preparing and defending the outlying villages, such as Daujontin, Perouse, &c. &c., thereby necessitating a much larger circle of investment, and costing the attack much time and loss, in having to assault them ; while on the other hand the admirable defence of Montbeliard by Von Werder, was due not a little to the care with which his position had been fortified, and also, it must be admitted, to the presence of nearly 40 siege guns, which he borrowed for the occasion from the batteries before Belfort.

Montbeliard.

It was, however, round Paris and Metz that use of such posts was made by the investing armies to an extent, perhaps, never before equalled.

The circle of investment was in each case so great, even in proportion to the large armies that occupied them, that success was greatly due to the telegraph, by which rapid concentration was secured, and still more to the numerous villages, parks, walls, &c., which lay round the cities, so that without extraordinary labour there were from the foreposts to the reserves successive lines of defence, with villages and parks as their bastions, and walls or shelter-trenches, abatis, &c., as their curtains : occasionally strengthened with field redoubts and breast-works, and with gun-pits for the artillery.

A sortie to be successful must have driven the defenders out of each of these in succession with ever-increasing difficulty, while the reserves were being continually strengthened with incoming troops from the flanks.

Investment of Metz.

The villages round Metz are generally straggling lines of low houses along the great roads, mostly of stone, and not easily loop-holed.

South of the fortress, and between the Moselle and the Sielle, the ground is low and rather flat, but from the latter stream eastward and northward, the ground is undulating, with small ravines which mostly radiate towards Metz. The great roads, following these, marked the lines of probable sortie, and the villages on them or on the ridges between them, became important posts. Thus, Mercy-les-Hauts was strengthened, and shelter-trenches were made between it and the road on its left

Between la Grange aux Bois and Ars Laquenexy the road runs between woods; these were partly cleared, and large use was made of the felled timber for abatis; the leading houses of the latter place (Fig. 4, Pl. II) were carefully loop-holed so as to sweep the road, on each side of which were abatis. From this village to Coiney the ground being level and open and suitable for earthworks, the position was strengthened by two strong field redoubts, the larger fit for perhaps 400 men and five or six guns.

The chateau of Aubigny (Fig. 5, Pl. II.) was very strongly prepared for defence, some of the walls having two tiers of loopholes; the timber in its neighbourhood was cleared away, and some shelter trenches were used in connection with it; by its position it commanded a ravine which the redoubt in its rear could not see into.

Beyond Coiney, Flanville and Montoy were held with a forepost at La

Planchette. Noisseville is the next strong point, and faced the French advanced posts at Nouilley. The outlying walls of this village were particularly well suited for defence; their general line is shown in Fig. 1, Pl. II.

Next along the line comes Servigny, which had been loopholed in the front and left flank. Poix and Failley, Charley and Olgy, strengthened the position as far as the Moselle.

The French advanced posts, too, made large use of the villages, &c., in strengthening their positions. The Chateau Grimont, in front of Fort St. Julien, is a good type of their arrangements; it consisted (Fig. 2, Pl. II) of a strong group of buildings loopholed to the front, and with a breast-work like a parallel in section, surrounding it; at A there was a barbette for one or two guns. This post was valuable, as it looked into a valley in front which could not be seen into by the fort. A good style of loophole was often used by the French riflemen; it consisted of a truncated cone of wicker-work, about 2 ft. 6 in. long and 9 in. and 4 in. in diameter at the ends; these buried in the earth of a shelter trench acted well and were light to carry up.

Beyond the river the valley is perfectly level and open, about as far west as the railway which runs at the foot of the rising ground. The holding of this valley was of great importance, as it seemed the direction in which a sortie could be made with most advantage, for in it lay the great road to Thionville, by which the army of Bazaine, once out, might have reached a refuge; accordingly the hamlets and villages were all important.

The Grandes and Petites Tapes and the hamlets of Les Maxes were perfect types of defensible posts, standing like islands in the plain. They were strongly built and the entrances to the enclosures were fairly flanked. Fig. 6, Pl. II, shows how the fire was arranged in the case of the Petites Tapes. The front alone appears to have been prepared.

On the main road itself is the village of St. Remy, where two Landwehr regiments were nearly destroyed in checking the great French sortie towards Thionville. The cover of its low walls, only breast high, and its houses, enabled them to last long enough to let the supports come up and defeat the attempt.

Post of Ladonchamps. One hundred and fifty metres south of St. Remy, and beside the road, lies the chateau of Ladonchamps, which the French recovered from the Germans during the investment, and which they considered of such importance that they made regular approaches to it to connect it with their works in rear.

The post (Fig. 3, Pl. II) consisted of a strong group of buildings surrounded by a bank and ditch with water in it, which added greatly to its strength; a trench and breastwork had been constructed by the French outside the ditch, with a blindage at A. This place had suffered more from artillery fire than almost any other; the ground between it and St. Remy was ploughed up with shells.

Further to the German rear, the position of Semecourt, was strengthened by a strong earthwork, with open gorge, and with casemated barracks and barbette for about 4 guns.

The hilly and wooded nature of the country along the western circle of investment, made sorties less likely and more difficult; but here, too, the great roads through Gravelotte to Verdun, and through St. Privat to Briery, were strongly held, and the country between these was secured with less difficulty. The former would have been very difficult to force, as from Rozerieulles it winds up a steep valley, devoid of cover and commanded by the plateau above.

Investment of Paris.

The great number of villages, walled parks, chateaux, villas, &c. round Paris, combined with the large extent of wooded ground, gave the investing army extraordinary advantages of cover, while the number and excellence of the roads prevented their lateral movements from being impeded. The French land-laws cause land to be very much sub-divided, particularly when it is so valuable as about the villages near Paris, and the object of each owner of a plot seemed to be to wall himself in. These walls were thin, of soft stone and mortar, and easily loop-holed or notched. For this reason it generally happened that the villages were bounded with rectangular enclosures, projecting more or less to the front as in (Fig. 1, Pl. II.) and often giving flanking as well as direct fire. The villages occupied by the French had the same advantages; but while sorties were obliged to take the offensive when their object was to break through, the investing forces could remain on the defensive.

North of St. Denis, on the low grounds about Deuil, there were miles of these walls all notched down at the top for the use of the investing troops. Brushwood was found convenient for forming banquettes, otherwise furniture or earth was employed.

In using the enclosures the precaution of providing wide gaps for retreat with a large front was always taken, and similar gaps gave circulation through walls perpendicular to the line of defence. Free circulation also was provided from room to room, or from house to house in defended buildings, a most important point in street fighting, &c. Gaps in the front line of walls were easily closed by shelter trenches or breastworks which were of all sizes from 2 feet wide and deep, to the sizes shewn in Fig. 29, Pl. VII., though rarely as large as those in the latter.

In the occupation of posts great attention was also paid to the provision of field casemates, timbers or rails for which were easily procurable.

Owing to the great extent of ground to be occupied, everything was done with the least possible labour. For this reason the walls were generally notched, instead of being loop-holed, or they had turf crenelations built on the top of them. In the houses, too, the windows were often filled with turf or furniture resting against the shutters, which were cut through for loop-holes. In places exposed to artillery fire walls seemed preferable to houses, as men feel less secure in the latter; though the effect of shells on houses, walls, &c., appeared to be very much less than might have been expected; a single shell generally made a hole 2 or 3 feet in diameter, which hardly ever brought the wall down even when an angle was struck. Thus in May, 1871, at the moment the troops of the Government got into Paris, the Communists manned one of the large gendarmerie barracks behind the ramparts, which were then in ruins, and they continued firing on the Bois-de-Bologne for some time after the heavy batteries had opened on them at only 600 to 800 yards range, though the shells could be seen to strike the building almost every time.

In one instance, a tall slight factory chimney, perhaps less than 3 feet in diameter, was pierced through and through near the top by a large shell without further injury.

Disposition of field redoubts. Earthworks, when thrown up, were placed in the open spaces as far to the rear as possible so as to leave a considerable extent of ground to be swept by their fire; this was the case with the redoubts covering the Engineer and Artillery parks behind the wood of Meudon and with those in the Haras to the west. Near Villa d'Avray, too, where a redoubt for 12 or more guns was placed at the intersection of the great avenues, the front was cleared and also protected by felling an immense quantity of timber, Fig. 7, Pl. III.

Dimensions of field redoubts. With regard to the dimensions of the field redoubts used by the Germans before Paris, Metz, &c., the parapets were from 6 ft to 12 ft. thick, and from 5 ft. to 8 ft. in height; the ditches varied from 6 ft. to 27 ft in width, and from 3 ft. to 9 ft. in depth—a good width seemed to be from 15 ft. to 18 ft., the depth being from 6 ft. to 8 ft; they were sometimes V shaped, but more often the escarps and counterscarps were cut at as steep a slope as the earth allowed.

When parapets were used for the gorges they were generally small and low, and the ditches were commonly not cut through at the entrance; or else a ramp led up from the bottom of the ditch to the level ground on each side, and by it the work was entered. No attempt appeared to have been made by the Germans to form caponiers in the ditches.

The trace consisted commonly of two faces with slight saliency, two short flanks, and sometimes a gorge (not always straight); the guns were generally placed at the salients or shoulders on barbettes.

Artillery positions. The artillery positions, particularly on the north-east, were generally in rear of the infantry posts; numbers of gun pits were made for them alongside the great roads. Thus there were pits for 24 guns along the Versailles road, to the south of Thiais; in these the guns stood on the surface of the ground, or the surface was slightly sunk. Figs. 13 and 14, Pl. IV. give sketches of these pits. Figs. 15 and 16 are limber pits, which were placed about 75 yards directly in rear of some gun pits in the open fields between Chevilly and Thiais. The pits shewn in Figs. 9 to 11, Pl. III., were formed of turf walls filled with earth, and were used by the road-side in front of the Haras position.

Use of abatis. Owing to the great extent of the woods, &c., immense use was made of abatis, particularly between the elbows of the Seine, between Sèvres and Bougival. This position, which was held by the fifth army corps, was felt to be of great importance, as a sortie on Versailles from under cover of Valerien was always to be expected. Three great lines or belts of abatis were formed; these by narrowing the area over which an attack could advance, would oblige it to keep to the lines of roads, along which the walls were loop-holed, and where special preparations were made for defence. The advance, for instance, from the open space about La Bergerie, which point was reached by the sortie of the 18th of January, was closed by the position of the Haras, a great open space of 1,000 metres by 500, enclosed by strong walls, along the rear of which there were placed two field redoubts (one of them, the only instance of a field bastioned line, as far as I know, used by the Germans, who did not here attempt to widen the ditch in front of the curtain, which is the common difficulty). The walls gave the place great strength, as they were strongly built, and the front one was flanked with stockaded tambours, (Corps Papers, Vol. XX., page 77) while gun-pits (Figs. 9 to 11, Pl III.) were placed at the eastern angle. In this neighbourhood there were but few houses, so more earthworks were used, many of them very small in section, as in Fig. 27, Pl. VII., with abatis in front; others were thrown up by the road-side, and strongly revetted with continuous hurdle work, well picketed in, which stood exceedingly well; with these works the line of abatis lay in the roads.

The walls of the parks of Metternicht, Malmaison, and of the chateaux of Busanval and St. Cloud, formed important portions of the defences. The first line extended from the Seine in rear of the Busanval park wall (which covered the outposts) through Garches to the park wall of St. Cloud; the second passed through the Haras to Villeneuve, and through the park of St. Cloud to the large redoubt in front of Villa d'Avray, at the eight cross roads. Figs. 7 and 8, Pl III.

The third position was still further in rear.

Along the southern front the advanced posts were protected by the chateau of Meudon, (forming the gorge of a strong earthwork which was never quite finished); the village of Bas Munden; the wall of the wood of Meudon; the villages of Clamart, Chatillon, Bagneaux, Bourge, and l'Hay; the front of the latter village was strongly intrenched with a large earthwork, having splinter-proof casemates, which were much wanted, owing to the close fire of the redoubt of Les Hauts Bruyères; and the enclosure walls round the gardens were barricaded with large wooden flower-pots and furniture. To the east, a long spoil bank had been turned to account by cutting oblique embrasures in it for six guns, and a rough blindage for the detachments was formed in a dung-hill; the most easy place to make it, probably, in the severe frost.

L'Hay being rather more forward than the next village, Chevilly, it flanked the front of the latter, and between them they swept the whole of the intermediate ground, which was perfectly open and level.

On the western side of l'Hay, and retired from the front, some batteries had been constructed in the park of the village which looked down the valley towards Montrouge. At Chevilly, the park wall and fosse formed a very strong post which swept the whole of the open country about it. Fig. 17, Pl. V., is a sketch showing the general plan of defence. From A to C the park wall had a wide fosse, Fig. 18, with a hedge outside; from A to B there is a high wall giving flank defence, and loopholed with two tiers of loopholes; at D, the entrance to the village was closed by a barricade across the great road. Further on, a breast-work was thrown up at E, which flanked the north-east enclosure wall, helped by a couple of houses in front.

The artillery for the defence on the east side appeared to be six guns, placed in gun-pits, as already described, in the open ground to the right rear of the enclosure, and close to the Imperial Route d'Antibes, which lies between Chevilly and Thiais. In addition, there was the great artillery position, already mentioned, along the Versailles road in rear of these villages.

Next to Chevilly comes Thiais, at the eastern shoulder of the plateau of Villejuif, (Fig. 19, Pl. V.) Most of the village lies low, beneath the brow of the plateau; but on the left is a strong cemetery, which is on high ground, and round which a ditch was dug, and the earth piled up against the wall; the tombstones were used on the top of the wall, and in some places two rows of loop-holes were obtained. The vaults and a field casemate gave good cover to the defenders. The enclosure walls of the village extended up to the edge of the plateau, (shown by the contour A, B, C,) and covered the infantry, while the cemetery flanked their front. Six gun-pits were thrown up to sweep the plateau; they were near the north-east corner of the walls, where the guns could be withdrawn by a lane into the village; and on the extreme right were two breastworks of low profile; the smaller one was for guns, and flanked the slope of the plateau that looked eastward. The right flank of the line reached the river at Choisy-le-Roy, the garden walls of which were very favourable for defence, as the French found on the occasion of their sortie on Choisy, previous to the one on Champigny.

From the other side of the river, the line of advanced posts ran through Mesley, Bonneuil, Chennevières, to Coeuilly; while the ridge of high ground from Villeneuve by Valenton, Boissy, Sucy, and Ormesson, provided a strong position in rear. The garden of the chateau of Coeuilly formed a salient point in the line (Fig. 25, Pl. VI.) and commanded the road from Chennevières to Villiers, which runs in a valley below it. The enclosure wall (Fig. 24) is strong and about 8 or 9 feet high on the outside; the northern entrance had a short length of parapet on each side, covered by a strong traverse, (with trench in rear.) The enclosure had the defect of being seen into by the heights above Champigny, distant about 800 metres; to remedy this, great labour was spent in forming large traverses (Figs. 23 and 24) of trees and fascines to protect the banquettes along the flank walls from being enfiladed. The western side was flanked by a battery of artillery posted at the edge of the Bois l'Abbé, while the hamlet outside the eastern side gave it flank defence, as did also the walls of the park, which extended eastward. The fruit trees on both sides were cut down and formed abatis. Further on, breastworks (of the section shewn in Figs. 28 & 29, Pl. VII) were thrown up alongside the road running below the railway bridge to Villiers. The object of these was to face the valley between Champigny and the railway embankment. Beyond this, the village and park of Villiers formed another salient position for holding the great road that runs west to Joinville le Pont. Some of the houses and garden walls were prepared for defence (Fig. 30, Pl. VII.), and in front of them was a breastwork for 6 guns (Fig. 31 and 32, Pl VIII.) Traverses were formed of gabions, and the detachments got cover in pits beside the guns which stood on the surface of the ground; these holes were partly covered, and abatis was placed in front and on the flanks of the breastwork, and a strong line of abatis of fruit trees was placed well to the front; it extended from the park wall to the railway, being completely swept by a cross fire. This part of the line was held by Saxon or Wurtemburg troops, who may have had muzzle loaders, for which this kind of gun-pit is suitable. The western corner of the park was strengthened by a stockade of round timbers, and its walls were occupied by infantry.

Use had also been made of shelter-trenches and gun-pits on the open ground in front of this position; and about 1,400 yards to the front, at the point where the plateau ends and the ground falls to the Marne, there was a breastwork of perhaps 80 yards in length across the road; its flanks (Fig. 33., Pl.VIII.) were simply formed of abatis, and a barrier stopped the road when required. The Saxon line crossed the Marne beyond Brie; Neuilly, Gagny, Clichy, Livry, and Sevran were occupied; while the fore-posts extended to Villemoble, and afterwards to Mont Avron and along the western skirts of the great wood of Bondy, in which the park and farm of Rancy were strongly held. From Sevran, the line of the Prussian guard-corps ran by Aunai-les-Bondy, Le-Blanc-Menil, and Dugny, in front of which their fore-posts extended along the Soisson railway and the stream of Le Moleret, which line was flanked by the important post of Le Bourget.

Eastern line.

Northern line.

The artillery positions were generally in rear, on the rising ground. They were very numerous about Stains and Pierrefitte, where also some of the siege batteries were placed. The spur of Les Faucelles was prepared for defence chiefly by a narrow deep trench, which also acted as a parallel to the siege batteries, and by entanglements of young fruit trees which were cut half through and laid down all the same way. Abatis was also used; and in the open ground to the north, earth breast-works and emplacements for guns were constructed. West of Pierrefitte, Montmagny was occupied, and Deuil with its endless garden walls gave the besiegers a strong footing in the flat ground below Montmerency, about which their main body seems to have been posted. Here also were batteries for the distant bombardment of the northern forts, and in rear of them the houses and park walls had been prepared for defence.

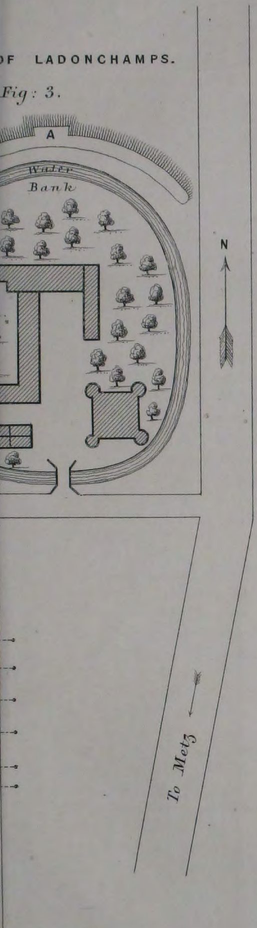
North-western line.

From Deuil the fore-posts extended by the Bains d'Enghein and the Bois d'Orgemont to Argenteuil; from this they held the right bank of the Seine to the elbow opposite Bougival. This line was fairly secured from sorties as the whole of the bridges were broken down. The island opposite Bougival, was occupied by an earth-work, which looked up the channel, and was strong in having the river for a wet ditch. It must be understood of course that there were many fluctuations in the advanced positions of the German armies; but the above is, a fairly correct sketch of those they occupied when once they were established.

Pl: II.

F LADONCHAMPS.

Fig: 3.



Scale for Fig: 3,_ 160 Feet_1 Inch.

50 0 100 200 300 400 500 Feet.

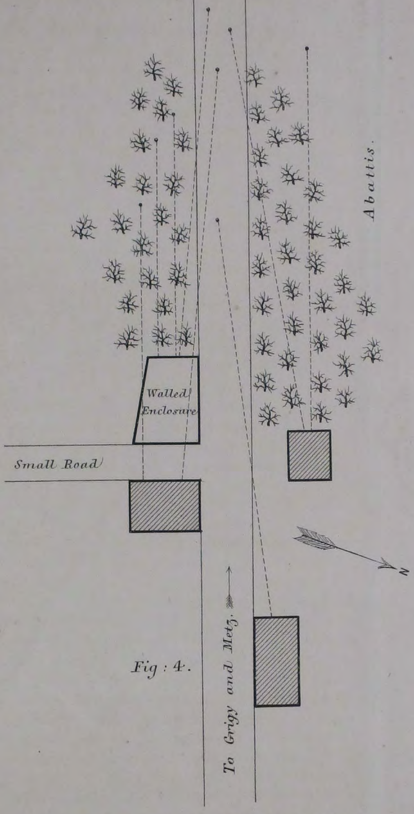


Fig: 4.

ENTRANCE TO ARS-LAQUENEXY NEAR METZ.

Scale: 80 Feet_1 Inch.

Kell, Bros. Lith.

Owing to the large quantities of siege materials collected near Meudon, and elsewhere, gabions were a good deal used for parapets. Figs. 21 and 22, Pl. VI. show a tambour to flank a wall near the above place.

Street fighting. Second siege. Parapets (like Fig. 22) were also found convenient in the second siege for screens across the streets up which the attack had to work, as they stood high and were quickly filled with sand bags. Elsewhere, wooden shields with thin plates of iron on them were used; they were about 7 feet high, of two thicknesses of 3 inch planks at right angles to each other.

In the paved streets the stones were found convenient for working out of a side street into a main one; they were handed along and thrown to the exposed side as in sapping, till a lodgment could be made for firing up the street (Fig. 26, Pl. VI). When the defence of the barricades was obstinate, advances were made by breaking through from house to house. Lieuts. Chermside and Noel, R.E., ascertained from some officers who were engaged in these attacks, that small charges of dynamite were frequently employed to blow in the partition walls; the advantage of this material over gunpowder being that a very small charge made an opening, and that the rest of the wall was not much shaken, while the attacking party could stand in the room ready to rush in through the gap. Even in the attacks of some of the villages, as at Chateaudun, the method of breaking through from house to house had to be resorted to.

Fig. 20, Pl. VI., is a sketch of a flanking loop-hole used by Communists from a balcony in the street of Neuilly; a side wall of paving stones and an end wall of sand bags were built up, so as to cover a man.

The principal barricades in the city were made with large earthen parapets and deep wide ditches like large field works. Accurate information about the position of these, and about the best ways of turning them, had been obtained by the Government previous to the assault. This enabled them regularly to arrange for the advance of each of the columns of attack. A field telegraph was laid down from Versailles to the Fort of Issy, from whence separate lines diverged to the heads of each column, so that the advance of each could be made to keep pace with that of all the others. The wire used was an insulated one, something like ours, and was supported, when possible, on houses, sticks, &c. The more hastily formed barricades were of furniture, carpets, billiard tables, kitchen ranges, boilers filled with earth, carts, carriages, &c., and of course, paving stones; these latter, like the sand bags in the British army, proved themselves to be the main stay of the citizen soldiers' operations.

T. F.

April, 1872.

PAPER III.

GUARD-ROOMS AND REGIMENTAL OFFICES IN BARRACKS.

By LIEUT.-COLONEL C. B. EWART, C.B.

A guard-room is required in every barrack. Its construction, in respect to general arrangement as regards the accessories usually attached to it, requires more care than might be at first supposed.

The regimental offices, where charges against prisoners are investigated, and the court-martial room, in which trials take place, should be in immediate connection with it. There should be a verandah in front of both guard-room and offices, where in wet weather either a sentry may walk, or prisoners with witnesses may wait under cover. The roof of this verandah must be high enough to admit of a sentry presenting arms with his bayonet fixed.

Attached to the guard-room must be—

(1.) "Prisoners' Room," for the reception of men placed in confinement who are neither drunk nor violent.

(2.) "Guard Room Cells," for men who may be drunk or violent.

(3.) "A Lavatory," for the men of the guard, or prisoners (accompanied by an escort).

(4.) "Latrines and Urinals," for both guard and prisoners.

The doors of both prisoners' room and cells should be fitted with examination slides, so that the non-commissioned officer in charge of the guard may be able to see to the safe custody and doings of the prisoners without opening the doors.

A urinal should be within access of the prisoners confined in the prisoners' room, to avoid their having to harrass the non-commissioned officer and men of the guard by calling them at night to unlock the door and escort them to the general urinal.

The windows of cells and prisoners' room should be as high as possible, and be covered inside with thick wire. Violent prisoners have been known to drive their fists through glass and cut a vein or artery in the arm. Windows of prisoners' rooms or cells should be entirely cut off from the barrack-yard, adjacent buildings, or streets, in order to prevent the introduction of liquor, tobacco, &c., from without.

Ceilings and roofs over prisoners' rooms and cells should be so strong that men in confinement cannot break through and escape.

Guard-rooms should be well ventilated, and there should be ample cubic space for the non-commissioned officers, drummer, bugler, or trumpeter, with

two-thirds of the strength of rank and file—the remaining third being always out on sentry.

There should be either a moveable arm rack, or one under the verandah for use by day, and one inside, near the door, for the arms at night.

The frame of the guard-bed should be of iron, and the wood-work forming the bed be made in compartments, to lift off for facilitating cleaning underneath.

A plan (Pl. IX.) is annexed of a guard-room designed to meet all these requirements, which was built at the Victoria Barracks, Windsor, in 1867, and the following are the particulars of the accommodation provided, the materials used, and the cost.

It must, however, be remarked that no paymaster's office was provided, because in the Guards, the paymasters' duties are performed by the quartermasters.

For regimental office establishments generally, a paymaster's office would be required for the paymaster and his sergeant clerk. It may be placed between the commanding officer's room and the court-martial room, being of the same dimensions as the former; or it may be in continuation of the offices shown on the plan, adjoining, but beyond, the court-martial room.

Guard House, Infantry Barracks, Windsor.

TABLE OF ACCOMMODATION.

ROOMS.	No.	Cubic space.	Water Tank.	How lighted.
		Cub. Ft.		
Court-Martial	1	4104	450 Gals. (over Latrine)	Not lighted
Commanding Officer's	1	2736	....	Ditto
Orderly	1	5572	....	Ditto
Guard	1	6028	....	Gas
Prisoners'	1	5572	....	Gas
Cells	5	950	....	Not lighted.

Materials.

WALLS—Of yellow and red stock bricks.
WINDOW SILLS—Of Portland stone.
DOOR STEPS AND HEARTH STONES—Of York stone.
ROOFS—Of fir, covered with countess slating.
DRAINS—Of earthenware.
WATER SUPPLY PIPES—Of wrought iron.

Date of commencement .... 10th January, 1867.
Date of completion .... 15th August, 1867.
Estimated cost .... £2,201 1s. 8½d.
Actual cost .... £2,178 5s. 5¼d.

C. B. E.

PAPER IV.

AN EQUILIBRIUM DROP DRAWBRIDGE.

BY LIEUTENANT J. F. LEWIS, R.E.

The bridge described below is designed to drop at the end next the counterscarp instead of to rise; it would be of use in such places as the ditches of retrenchments, where it might be desirable to leave the bridge standing to the last minute, and where the enemy might even be upon it before it could be drawn.

The following conditions have been observed:—

1. The bridge should drop at the end next the counterscarp.
2. It should always be in equilibrium, and thus easy to move; to satisfy this condition the centre of gravity must move in a horizontal line.
3. When drawn it should cover the gateway.
4. It should leave nothing to facilitate the crossing of the ditch by the enemy.

The bridge consists of a platform, AC (Fig. 4), resting at one end against the escarp wall, and suspended at the other by a chain, BC, attached to the escarp. When drawn in, the outer end, C, of the bridge moves in the arc of a circle whose centre is B, and radius BC; the centre of gravity moves in a horizontal line, and the inner end, A, in a particular curve.

First, to find the proper proportions of AB, AC, BC,

Let $AB = c$, $BC = a$, $AC = b$,

Then, when the bridge is in a horizontal position,

$$a^2 = b^2 + c^2 \quad \ldots\ldots\ldots\ldots \quad (1.)$$

Again, assuming that the bridge is of uniform construction, and thus bisected at its centre of gravity, then when it is in a vertical position

$$a - \frac{b}{2} = c \quad \ldots\ldots\ldots\ldots \quad (2.)$$

These equations, when worked out, give

$$c = \frac{3}{4}\,b \qquad a = \frac{5}{4}\,b$$

$$\therefore\ a : b : c :: 5 : 4 : 3$$

With a gateway 7 ft. high to be closed by $\frac{1}{2}\,b$, we have

a = length of chain = 17 ft. 6 in.

b = length of bridge = 14 ft.

c = height above roadway of the point of attachment of the chain = 10 ft. 6 in.

Second, to trace the curve in which the inner end of the bridge must move.

This may be most easily done by drawing the bridge in different positions, and marking the path in which this end travels.

RAWE

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The co-ordinates to the curve may also be found from the following three equations; where

$\alpha =$ the angle made by a with the vertical,

$\beta =$ the angle made by b with the horizontal,

and the origin of co-ordinates is at the point where the inner end of the bridge rests when horizontal.

$$a \sin \alpha = b \cos \beta - x \quad \ldots\ldots \quad (1.)$$

$$y = \frac{b}{2} \sin \beta \quad \ldots\ldots \quad (2.)$$

$$y = a \cos \alpha - c \quad \ldots\ldots \quad (3.)$$

These give $x = \sqrt{b^2 - 4c^2 + 8ac \cos \alpha - 4a^2 \cos^2 \alpha} - a \sin \alpha$,

and the equation to the curve is

$$x = \sqrt{b^2 - 4y^2} - \sqrt{a^2 - c^2 - y^2 - 2cy}.$$

This curve should be cut in the masonry of the gateway; it might be faced with a thin strip of iron to prevent it wearing away, and the inner end of the bridge should have runners to move on it.

The method of drawing the bridge was suggested by Lieut. Spaight, R.E. It consists in attaching a horizontal bar to the bridge at the centre of gravity, or at some point in a line drawn through the centre of gravity perpendicular to the plane in which the bridge moves. The advantages of placing the bar in this position are that it works horizontally, and that no cross strain is brought on it by unequal loading of the bridge. A stout pin run through a hole in the bar will hold the bridge in any required position.

To find the stress, T, brought on the bar by a weight at one end of the bridge,

Since the weight of AC, the tension of BC, and the reaction at A, are in equilibrium, the directions of these forces pass through the same point. Taking moments about this point, which is the centre of BC, we have

$$T \times \frac{c}{2} = W \times \frac{b}{2}$$

$$T = W \cdot \frac{b}{c}$$

This is a tension when W is at A, supposing that end of the bridge to be unsupported, and a compression when it is at C.

For intermediate positions of W, T varies between these extreme values.

In Pl. X., Figs. 1 and 2, the bridge is represented as half drawn in. The side view shows the moving gear, which the rear view gives in section. The front view shows the position of the chain, the curve with the runner working on it, and the slot that has to be cut in the wall to take the main girders when the bridge is in. Fig. 3 is a front view of the bridge when lowered.

In the above calculations the weight of the chain has been neglected. It would produce an inward pull when the bridge was out, diminishing to nothing as the bridge was drawn.

J. F. L.

PAPER V.

NOTES ON ECLIPSE PHOTOGRAPHY IN CEYLON.

By CAPTAIN J. R. HOGG, R.E.

Solar eclipses, such as that observed in southern India in December, 1871, afford such valuable opportunities of research that a few notes of the photographic work at Jaffna on that occasion may, at some future day, be of use to officers of the corps if they should, at short notice, be called upon to conduct a similar operation.

The expedition despatched in that year, partly under the auspices of the British government, divided at Point de Galle into two parties, one of which proceeded to the Malabar coast, the other to Jaffna, by way of Trincomalie. At Jaffna, some days were spent in erecting instruments and an observatory for their protection; no morning of these days held out much hope of the sun being unobscured on December 12th, but when that day dawned the eastward sky was practically clear, and all the operations undertaken met with successful results.

For two of the instruments on their equatorial mounts, viz., a polariscope and the photographic camera, an observatory in the shape of a *tente d'abris*, 30 ft. by 17 ft., was constructed with its length on the meridian line, of palmyra rafters, thatched to a height of 5 ft. and thence upwards covered with tarpaulins, which could be rolled up to the ridge-piece by means of brail ropes. A length of 6 ft. from one end was closed altogether with tarpaulins to serve as a dark room, the interior of which was lined with matting and yellow cloth; at the door of this extemporized laboratory the camera was set up.

The accompanying sketch may serve to illustrate the apparatus employed: —An equatorial mount, by Messrs. Cooke & Sons, carried a 4-in. telescope upon which a camera of special construction was strapped; the latter, though adapted only to 5-in. plates, was long enough to shroud the front of a Dallmeyer doublet lens that had a back focus of 26 inches; this lens, as well as the telescope and several other instruments, was lent by Lord Lindsay for the use of the expeditionary party. Above this again, a Kinnear camera was mounted on its side, carrying a Ross single lens of 16-in. focus. The long camera was furnished with six backs, and dipping baths in equal number were provided, so that a set of 5-in. plates could be sensitized simultaneously just before totality set in; the Kinnear camera was added as an experiment for the purpose of keeping one plate exposed during the whole period of totality, whilst the others were being successively exposed and removed.

The baths having been ranged out in line in the dark room, and the corresponding slides on an upper shelf immediately above them, the plates were coated with Thomas' bromo-iodized collodion, and sensitized in a 40-grain solution for two or three minutes; they were then backed with sheets of blotting paper soaked in distilled water and put into the slides; this precaution helped greatly to keep down the temperature of the films. As totality approached, the external air chilled rapidly, but the camera remained heated, and the dark room, cased, as it unavoidably was, in tarpaulins that had been exposed to the sun till nearly 8 a.m., contained an atmosphere ill-suited to photographic processes. Moreover, although all possible speed was given to the operations, the last plate was out of the bath for fully a quarter of an hour, rather a long time for the tropics, but the development proceeded, nevertheless, with tolerable ease.

The exposures were conducted as follows:—A few minutes before totality, the slides, ranged in order in a box, were carried out of the dark room and held in readiness, whilst the regulator of the clock was given its final adjustment. This important operation would have been comparatively easy had it been possible to discard the large telescope and to attach its finder to the long camera, and if the upper camera had also been dispensed with; but, as it stood, the load carried by the equatorial instrument was cumbrous and difficult to balance in continuous rotation. However, the final adjustment made it follow the sun steadily for the requisite period. At the moment of totality the seconds were counted aloud from the chronometer; one operator opened and closed the shutter in front of the lens at the appointed seconds; another handed the slides from the box, and returned them to it; whilst the third put them into the camera and exposed the plates. Starting from the instant of totality, the front shutter regulated the exposures according to the following ordinal numbers of seconds, which were emphasized by the counter:—

Open	5	30	51	96	121
Shut	20	45	90	115	131
thus giving	15	15	39	19	10 seconds,

respectively, to the five plates in the long camera. The plate in the upper camera was exposed from the eighth second until the last one below had been shut up. This operation required a little care in its performance, and was, therefore, practised on the day previous to the eclipse.

By the time that the slide was withdrawn from the upper camera, the five slides from the lower one had been carried into the dark room and ranged out in line ready for opening. In development, the formulæ recommended for use with the collodion, by its makers, were employed, although a stronger bath was used than that prescribed to consist with them. As quickly as each plate could be drawn from its slide, and the dried paper scraped from its back, it was developed with the 15-grain iron solution and acetic acid, and then put into a dish of distilled water to wait till all its successors had been so treated. Each dish was then drained off and refilled, and the plates in succession taken out and intensified with the 2-grain solution of pyrogallic acid, silver, and citric acid; they were then put back into the dishes, and finally washed under a stream before fixing with hyposulphite of soda.

Although the image of the dark moon had only a diameter of about $\frac{3}{10}$ths of an inch, the negatives thus obtained exhibited a large amount of corona with well marked features and confirmation of rifts; the projections of luminous rays from the sun's disc could be measured definitely to an apparent extent of fully 340,000 miles. The best negative was that obtained in the middle of totality by an exposure of 39 seconds; the least successful one, that which was exposed in the upper camera for about two minutes; the latter showed abundance of corona, but was blurred by the vibration of the whole apparatus, which vibration each change of slide in the lower camera inevitably set up; this negative is probably, in consequence, of little value.

The negatives were left unvarnished, so that they might be taken home by the expeditionary party for examination and enlargement; unfortunately, no prints have as yet been sent out, so that sketches from them cannot at present be added in illustration of this paper.

In the accompanying sketch of the apparatus employed, the telescope and cameras are, for the sake of illustration, shown turned round a quarter circle from their working position, and, to avoid needless complication, the fastenings of the cameras, which had to be rudely extemporized at Jaffna, have been omitted.

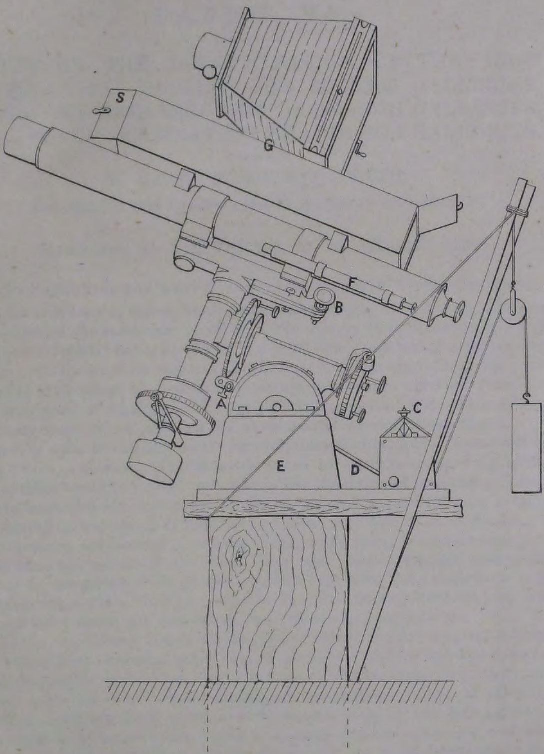
J. R. H.

Trincomalie, Aug., 1872.

SOLAR ECLIPSE OF 1871.

Sketch of Apparatus employed in Photography at.

JAFFNA.



A.B. *Slow motion screws for r.t ascension and declination.*
C *Regulator of clock.*
D *Pinion driving rod.*
E *Cast Iron bed plate.*
F *Telescope finder.*
G *Cameras with lenses of 26 in. and 16 in. foci.*
S *Exposing shutter.*

J. R. Hogg Capt. R.E.

PAPER VI.

NOTES ON THE DETERMINATION OF THE MOST PRACTICAL SECTION FOR MINING GALLERIES, ON THE BREAKING OUT OF BRANCH GALLERIES, AND ON VENTILATING SHAFTS FOR GALLERIES.

By HENRY BARON VON SCHOLL,

Colonel of the Imperial Royal Austrian Engineers.*

Translated by LIEUTENANT T. H. ANSTEY, R.E.

1.—To Determine the most Practical Section for Mining Galleries.

As far as is known, miners in all armies when engaged in driving galleries in presence of the enemy, or in other words driving them under-ground and with great rapidity, have, up to within a short time, made use of a rectangular section. To justify their choice of this form, it has been argued that the wood placed at the disposal of the miners is always delivered in a straight form, and that with wood of that description the different component parts of the gallery frame are easily made, provided the above mentioned section be adopted.

There is much in this argument; for everything that is needful in war should be as simple as possible. This should be borne in mind more especially in the case of those works in time of war, which, like the lining of projected galleries, have to be carried out in presence of the enemy, and not unfrequently by persons having no knowledge of carpentry, as is the case with so many miners.

If, however, we discover a section which, while being more ingenious, yet, at the same time admits of the lining being made more easily, and enables the gallery to be driven with greater rapidity—we must take these facts into consideration as well; for if we neglect them, the enemy may not do so, and then (all else being equal) the victory will be with *him* and not with us.

To leave the military miner, for the present, out of the question, and to note how others have penetrated into "mother earth," we find innumerable cases in which the section adopted has by no means been the rectangular one. Ordinary miners, whose art bears in many respects great resemblance to that of the military miner, and who have to work with straight wood to line their galleries, have used for a thousand years past a standing trapezium, the roof and the somewhat broader floor being parallel, the walls being at an equal slope. We clearly see in this the endeavour to strengthen the roof (collar) piece, which is most exposed to the pressure of the earth, more than it would be possible to do if the rectangular section were used.

* Now General, and Minister for National Defence.

Brunel, who tunnelled beneath the Thames, and railway engineers who have burrowed beneath mountains, working with much larger dimensions than the military miner has ever any occasion to employ, used the segment of the ellipse, even from the very commencement of their task, and while working with only the provisional lining. They sought therein a greater strength of construction by giving a curve to the roof and walls, and thus conducting the pressure on the roof as much as possible to the sides.

In one respect, however, far more remarkable constructions are shown us by the animal world living beneath the ground. They frequently shew us passages constructed in mere sand, without any lining whatever, and driven crooked and straight in every direction, and yet standing for years. In these cases we never find the rectangular section employed, but such a one as approaches more to the ellipse or circle.

Without wishing for a moment to draw a parallel between the work of these cunning troglodytes and the arrangements of the military miner, yet it strikes one forcibly how well the former understand the art of burrowing in the earth, (often, indeed, with great rapidity,)and of constructing permanent abodes without employing any lining to support roof or walls. Thus, indications are not wanting to justify the belief that the sectional form of a gallery is an essential point, and that as much regard as possible should be paid to it; for why should ordinary miners, engineers, and the subterranean populations of the animal world have worked—the two former by exercise of reason, the latter by instinct—in one particular way, and in no other? Bearing these indications in mind, let us return to the military miner, and if we wish to ascertain the most practical form for his galleries, we must lay down the following conditions:—

1. There must be space sufficient for the miner to work and move about in the gallery.

2. The pressure of the earth must not be allowed to act directly on the gallery, but as far as possible be conducted down the walls and beneath the floor, in order that the roof and walls may stand at least long enough to enable the miner to work forward and thus to place the lining. The miner should advance under the protection of a natural arch of earth, and thus avoid the great delay which is inseparable from *driving*.

3. The lining must, as far as possible, correspond to the nature of the wood, and to the capabilities of the men working the gallery, in order that straight timber may be adapted after a little manipulation, and the miner, though he be ignorant of carpentry, be able, after a little practice, to arrange the different pieces and put the frames together.

To look at these conditions more closely—

Remark No. 1. If we contemplate the outline of the human figure—either standing, squatting, or kneeling, in front or behind—and suppose the man so represented be working with a pick, and we join the extremities of the said outline, viz., top of head, shoulders, elbows, and the soles of the feet by lines, we find that the upright ellipse, cut off below, is the regular figure which approaches most nearly to the form we have obtained. This ellipse must, of course, be increased in height as well as in breadth, in order to ensure sufficient freedom in working. The height of the ellipse will depend both on the size of the human being and on his attitude while working, whether standing, squatting, or kneeling, so that we get three different measures for height, and consequently three different sizes for galleries.

Greater space than is thus determined is not necessary for the actual driving of the gallery.

If we envelope this ellipse with a rectangle, the miner would certainly be able to work as comfortably in the gallery so formed ; but the speed of advance would be greatly diminished, as to obtain the greater sectional area, more earth would have to be excavated.

Remark 2. The nature of the earth is not, as a rule, of sufficient consistency to make it immaterial in what form the roof and walls are made.

A soil which is not stone, or become hardened like stone, seldom admits of a flat roof for galleries of the breadth required for military mining, so that there is always danger of such galleries falling in. The less consistent the soil the higher the arch must be raised, and we hold that the necessary concavity is in inverse ratio to the consistency of the soil.

Among the natural forms of arch thus obtained, there are three, manifestly differing from each other, viz.: The flat elliptical curve, (basket handle); the segment of a circle ; and the half ellipse, placed with its longer axis vertical. As this last is the one corresponding most nearly to the form discussed in Remark No. 1, the other two need not be further alluded to.

Now let us attempt to decide which is the best form to give the walls. As regards durability, we can in many cases keep them quite vertical, without fear for the result; but as already stated in Remark No. 1, the breadth of the gallery may be much less at the sole; therefore it follows as a matter of course that we willingly utilise the base of the slope thus obtained, and the more so, that less earth need be excavated, and thus the rapidity of driving the gallery be increased. We shall observe this more in great galleries than in smaller ones, the excavation of earth being much greater in the former, as the walls of the latter are much lower, and the galleries themselves in all probability much narrower; the roof will therefore be less weighted, and consequently the base of the slope may be much more easily dispensed with.

In choosing between the straight or concave lining for the walls, we prefer the latter, because, as shewn in Remark No. 1, the concave form corresponds more nearly to the necessary space required for working, allowing as it does for the knees of the miner, which frequently project beyond the sole, especially if he happen to be working sideways.

The effect of giving concavity to the wall is to give a continuous curve from the point of the arch to the sole.

Remark No 3. With the help of boards or planks cut outside to the form of the section determined on, fastened together like the centering of a bricklayer's arch, with a straight piece laid flat on the ground to form a sill, there should be no difficulty in making a frame of the shape of the segment of an ellipse ;

as little difficulty would be experienced in fitting the sheeting of boards to the outside of the frames, for the latter have such a slight curve, that the pressure of the earth would be sufficient, owing to the elasticity of the wood, to compel the boards to fit close to the frames.

It is different, however, when we come to the planks forming the sheeting of the roof, which if they were of a certain breadth would either not fit close to the frame at all, or else would split. If they did not fit close we should get a polygon instead of an arch, and the boards would not abut one against another like the voussoirs of an arch; again, if the boards were to split, they would lose strength, especially if the split of the plank accidentally ran out in the space between any two frames.

If to combat this we took narrower planks, which, consequently, would fit almost close to the frame, we should be no better off, because two planks which together are as broad as one, have nothing like the same strength, on account of the joint running between them.

It must also be borne in mind that the pressure on the roof is very much greater than on the sides, and that the nearer the planks approach to the crown of the arch the more horizontally they are placed, and, consequently, less favourably situated for resisting transverse strain. These disadvantages attaching to the elliptical curve—which cannot be overlooked, and which merely relate to the crown of the arch, described with a smaller radius than the sections immediately in contact with it—can only be overcome by an alteration in the form, and that, by neglecting the sharp curve altogether, and by prolonging the side walls, with their flatter curve, until they meet in a point above the former crown. It is true that by doing this we somewhat increase the quantity of earth to be excavated, and thus delay the work, but this loss is more than counterbalanced by the following advantages:—

(*a.*) That we can attach the planks forming the sheeting to the frames at the crown as easily as at the sides.

(*b.*) That we get a far more favourable position for the planks at the crown with respect to transverse strain (nearly 45 deg. to the horizon), so that their thickness need not be increased.

(*c.*) That on account of the wedge shape of the frame at the top, the pressure of the earth is much more easily conducted down behind the walls.

(*d.*) That it is much easier to make this new section with wood which has been originally straight, because the two halves of the horse-shoe retain the flatter curve of the sides, right up to the crown.

Having determined in this manner that the most practical form for mining galleries is the gothic arch, with the walls curved inwards towards the sill (in fact, the simple Arabic arch), we will go more closely into the matter of the dimensions. In doing this, we must, as already stated, be guided by the size of the human frame. The dimensions must be taken to the sheeting and not to the frames, it being sufficient if the latter are large enough to admit of passage, as the work would go on principally in the intervals between them.

Considering the fact that the human skull is round at the top, and that for that reason the point of the gothic arch should always be some inches above it, the measure taken might be: for a miner standing, 6 ft.*; squatting, 4½ ft.; and kneeling, 4 ft.; so that a man 5½ ft. high could work comfortably under all circumstances. If, however, without considering the comfort of the miner, we take it for granted that he stoops somewhat in each of these three attitudes—in the first more than in the second, and in the second more than in the third—we may assume, without hesitation, the necessary height in the first case to be about 5 ft.; in the second, about 4 ft.; and in the third, 3½ ft.; bearing in mind, moreover, this advantage, that the less earth excavated the quicker the gallery will be pushed on. So much for the height. To pass on to the requisite breadth of the gallery, we must consider that the miner requires a minimum breadth of 2½ ft., in order not only to remain in the gallery, but to be able to work comfortably. We willingly give this breadth to the smallest galleries, for they are terminal galleries, and we may assume that there is no occasion to make room for miners passing each other. This, however, must be allowed for in galleries of medium size, in which we may confine ourselves to providing sufficient space to allow two men to pass, viz., a breadth of 3 ft., which would fully meet the case. Lastly, in the great galleries where probably there would be the greatest circulation, we shall be justified in taking the breadth at 4 ft., as two men can pass each other easily in that width. Considering further that it is very advantageous in changing from one section to another, to keep the true spring of the arch, or, in other words, the point of greatest breadth in the galleries, at the same height, so that planks of the same size may be used for sheeting, at any rate up to the spring of the arch, we shall find that the height of the spring is placed most conveniently at 1½ ft. above the sole, which, even in galleries of smallest section, and of the dimensions already stated, will allow the arms of the gothic arch to be at such an angle as will admit of the planks near the apex having sufficient inclination to the horizon to ensure their retaining the requisite strength. To decide the form of section by reversing the above conditions:—Taking the height of the spring of the arch at 1½ ft. above the sole, the breadth of the large galleries at 4 ft., the medium at 3 ft., and the small at 2½ ft., and taking as centre, for each limb of the gothic arch, the spring of the opposite arch, 1½ ft. above the sole (a mode of construction easily remembered), we get heights up to the sheeting which very nearly agree with the ones already mentioned, viz., for the large, 5 ft.; for the medium, 4 ft. 1 in.; and for the small, 3 ft. 8 in. We prefer, then, to take these figures as our basis; they agree very nearly with the dimensions already quoted, and are very practical, the size of galleries being entirely influenced by their breadth on plan.

In dealing with small galleries, where, on account of the lowness of the walls, the length of the versine to the curve is very small, we can obtain the same strength in the curve from the sole to the spring, and from thence to the point of the arch, by using wood of the dimensions of so-called *staffel holz* † instead of

* It must be borne in mind that the dimensions used in this Paper are Austrian, and that the Austrian foot is equal to 1·03704 English feet.—EDITOR.

† *Staffel holz* has been described to the translator as "a special wood only used in the south of Germany, and means a wooden beam of small rectangular section, for instance, 3, 4, or 5 in. thick, and 3, 4, or 5 in. broad."

boards or planks; and when, instead of broad planks or boards, only *staffel holz* is at our disposal, we can make the walls from the sole to the spring of the arch vertical, the difference in the quantity of earth excavated in the two cases being almost inappreciable. Under these circumstances, the gallery would be of sufficient breadth at the sole to admit of the use of the miner's truck; but this would not often occur, as the width of 2½ ft. would be only at the mouth, and after that for the short distances between the frames, so that the work could be done well enough with the hand or shovel.

The greater rapidity attained in driving galleries of gothic, over those of rectangular, sections, is augmented by the fact that the frames take less time to place in position, because the two curved sides can be easily made into one solid piece by using crown plates, and if the horse-shoe thus obtained be set up on the sole-piece, the miner need not test its position relatively to the sides, as by merely setting it up his object is gained, and it maintains its position permanently.

All the above, concerning the most practical form for mining galleries, has been known since the year 1857, and not merely on paper.

The experiments conducted by the 7th Battalion of Engineers, under the able superintendence of (then) Lieutenant Koller, showed at once, notwithstanding that the miners were used only to the rectangular section, that gothic galleries could be driven twice as quickly, and with practice three times as quickly, as rectangular ones of the *same sectional area.* These experiments were repeated late in the autumn by order of the Engineer Brigadier General at the time, Major General Chevalier de Maly, to whom the science of fortification owes so much, by driving three galleries simultaneously, viz., two rectangular and one gothic. The best men of the 7th and 8th Engineer Battalions were purposely detailed to the rectangular galleries, and men of the 5th Engineer Battalion, who up to that time had never worked with gothic frames, were told off to the gothic gallery. The special direction of the whole experiment was entrusted to that expert officer (then) Captain Steutter, of the 5th Engineer Battalion.

Although it was intended that the ground should be of the same description for each gallery, yet it so happened that the soil in which the gothic gallery was worked, turned out to be of a less favourable character than in either of the two others. In spite of the inexperience of the men of the 5th Battalion, it was found that in adverse soil the rapidity of advance with gothic galleries was double as quick as that of the rectangular ones, the sectional areas of each gallery being equal. Moreover, the miners of the 5th Battalion working with the gothic frames had penetrated during the first "field" so rapidly into the ground, while miners working with the rectangular frames got so far behind, that Captain Steutter was compelled to stop the work in the gothic gallery till the first "field" in the other one was completed, so that the above comparison only commenced from the second "field."

In soil less unfavourable to mining operations, the difference will probably not be so great. There will always be a certain difference in favour of the gothic galleries, for if we compare gothic and rectangular galleries of equal sectional area, it is evident that the miners in the former work much more at their ease, on account of their greater height; and comparing galleries of equal breadth and height, the excavation in the case of gothic galleries is less, and they have all the advantage of having frames which are more easily placed.

Where mining galleries are exposed to the shock of neighbouring explosions, the gothic form of section gives much greater strength of resistance. This advantage, which in the year 1857, was only surmised, was abundantly proved by the comparative experiments carried out by the Engineer Battalion at Krems, under the direction of Major Maywald, who has done so much in mining matters, by order of the K. K. Genie-Comité.

In the case of two galleries, one of gothic, the other of rectangular section, placed equidistant from a mine, the latter was broken in for a length of several feet, while the former remained uninjured. There was also constructed underneath the same mine and at but a short distance from it, another gothic gallery, which likewise remained intact after the explosion. This accessory advantage of gothic galleries must, without doubt, necessitate a slight change in the formula for size of charge, for it may easily happen that otherwise, if the enemy uses galleries of gothic form, they may not be destroyed by the present charges. Gothic galleries have another advantage in peace time, viz., that the operation of taking them to pieces is much less dangerous, and that it is much easier to recover all the wood which has been used in the construction of the gallery.

Many other experiments were made at Verona, in 1857 and 1858, in order to ascertain if gothic galleries could be used in the most difficult cases in mining.

Trials were made in changing from one profile to another, windings, branch galleries, breaking out from round and square wells, and especially commencing galleries in slopes of different descriptions of ground, amongst others in the pulverized soil of the crater of a mine which had been exploded in the previous year, without anything being found to make them compare unfavourably with the rectangular galleries.

In all these experiments wooden frames were used, and the different pieces composing the frames attached together at the sides by means of oak nails, and at the crown by bolts and nuts. The more exact detail of these frames is shown in Plate XII.

It would, however, be advisable to have these frames made entirely of iron, as was done in the defence works at Venice in 1859, They have the advantage of greater durability, which is not only an advantage in time of peace, but the Engineers have them then always ready to hand. Besides this, the width of the walls and the height of the sole-piece is lessened, so that we get greater breadth and height, and the sole-piece need no longer be let into the ground.

The horse-shoe portion would be best made of T iron, bent to the proper shape, the flange being next the earth, thus forming a smooth bed for the sheeting. The sole-piece might, for the sake of economy, be made of cast-iron, as it is less exposed to blows of the hammer.

The use of iron in preference to wood in making galleries, leads us to consider the practicability of rendering them, as far as possible, secure from the shocks of neighbouring explosions, the experiments at Krems having proved that the mere alteration in the form of the wall is of service. Especial strength might be attained without any sacrifice of rapidity of progress, by introducing, from time to time, other frames in the completed field between two frames more or less distant from each other. At the same time, in contemplating the advantages accruing from the use of iron frames, the wooden ones must not be neglected, for in war time it might so happen that the stock of iron frames might fail, and nothing but wood be available.

We are far from thinking that the form for gothic galleries, and the construction of the frames, as described above, is not to be improved on. Further experiments might make modifications of form and construction desirable; we believe, however, from the results practically obtained that a turning point has come in the history of mining operations, for the fact of the miner being able to attain his object much more rapidly, will be of greater value and turned to more account than heretofore, more especially as, owing to the improvement of fire-arms, the task of his companion, the sapper, has much increased in difficulty. Taking a simple case:—A gallery has to be driven from the third parallel under a glacis which is not countermined, against a counterscarp wall, distant 80 ft., to admit of the descent into the ditch, in soil similar to the Veronese. The miner would require, with the rectangular gallery, ten days; but with the gothic—each field being 3 ft. long, and allowing two hours per field—only five days' work! This difference of five days in such a late, and, therefore, important part of the siege, ought to be of too great importance to allow these alterations being looked upon with indifference. Lastly, it is reasonable to expect that with continual practice a still greater rapidity of advance might be attained, for, as far back as the year 1857, a Corporal Spinelli, of the 1st Company, of the 7th Battalion of Engineers, proved practically that a field, 3 ft. long, of medium size (*i e.* 3 ft. broad and 4 ft. 1 in. high) can be finished in 1 hour and 31 minutes. Especial skill being brought to bear, an increase in the rapidity of advance might be obtained by making the field 4 ft. long, as was done by the 7th Battalion, in 1858, by which the time taken in putting up one frame was saved in every 12 ft. of length of gallery. It has also this advantage, that in each field of a large or medium gallery, the section of the next sized one easily fits in where a branch is intended to be made.

II.—On Breaking out a Branch Gallery from one already Constructed.

In the practice of mining, there are few things which offer greater difficulties than commencing a new gallery from any point of an old one, especially if the soil be loose and the proceeding be conducted in the ordinary manner; but the difficulty vanishes if the right means be adopted, as follows:—

1. The frames of the old gallery must be sufficiently far apart to admit of the new gallery being commenced between them, besides having six or seven inches to spare on either side.

2. The height of the new gallery must be always less than that of the old one. These two requirements never clash with the uses to which the galleries are to be put in actual warfare.

3. If the direction of the new gallery, AB, Pl. XIII., Fig. 1, be oblique, as is usually the case, break out at C and not at A, as at A there are two operations to be performed—the breaking out, and the changing direction. It is much easier to break out at C and turn afterwards at B, the distance BC being at least 3 ft. Breaking out at A, there is an acute angle in the earth to contend with, whereas at C this becomes a right-angle, and much more stability is obtained.

Granted so far, it depends now upon the stability of the soil what method to adopt. Here the worst case will be considered, viz., loose gravel or sand.

The point to be broken out at being fixed (Figs. 2, 3, and 4), take an iron shield, bent to the concavity of the sides of the old gallery and shaped to the section of the new gallery, fix it on the point selected by nails or screws to the planks of the old gallery, and shore it up against the future pressure of the earth without by a couple of beams, A and B, bearing against the opposite side of the gallery. Then take a frame representing an envelope over the new gallery section and attach it likewise to the lining of the old gallery, leaving sufficient space to allow of the planks of the new gallery and the wedges to be passed between. Now cut out the portion of the planks visible in this space with a knife or saw (Fig. 3). Next put two frames of the new gallery, C and D (Fig. 2), upright in the old one, in order to use them as leaders for the planks. One of these frames should be put close to the side, the other one in the centre of the old gallery. Cover these frames with the planks which are to form the sheeting for the new gallery, and which have to be driven into the earth in the space left between the shield and its envelope, at the same time fastening the ends projecting over the frame placed in the centre of the gallery to the ground, by means of a rope passed over them and then pegged to the ground on each side. As soon as these planks have been driven a sufficient distance into the ground, the shield should be removed, and the earth in the new gallery removed as far as the ends of the planks. This should be far enough to place the first frame of the new gallery. This done, take away the provisional frame D; drive the planks further into the earth till there is room to place the second frame of the gallery, after which frame C may also be removed, and the old gallery left clear.

In cases where the soil is less loose, many of these details may be omitted, for instance, the shield, and sometimes even the provisional frames, particularly when the soil is damp, for in that case even gravel or sand has sufficient stability for a certain time.

To admit of the planks being driven more easily they might be sharpened, and it would be still better, if iron planks were used instead of wood, as they are so much thinner.

The first field of the new gallery ought to be shorter than the ordinary ones, because it is never used to break out from laterally, and the second frame is placed all the quicker, and, furthermore, because the weakened part of the subterraneous structure gains additional strength, which is a consideration of some importance with regard to possible explosions in the neighbourhood. As soon as the second field of normal length is finished, turn the gallery in the prescribed direction. This turning is of easy accomplishment with gothic frames, flexible planks being used to sheet the frames in the turning field, and the first one of the new gallery. Birch wood is the best for the flexible planks, and they should be made very thin, the required strength being obtained by applying them double or treble, according to circumstances.

Figs. 2, 3, and 4, represent galleries made with iron frames. With wood frames the principle of breaking out remains the same.

All the above remarks being addressed to those possessing some knowledge of mining, many of the ordinary details are omitted.

Ventilating Shafts for Mining Galleries.

The work in a mining gallery is very often interrupted merely by the evaporation from the men's bodies, especially in summer and when the entrance is exposed to the rays of the sun. Ventilation, therefore, becomes necessary, and this is commonly obtained by driving in fresh air, and pumping out the foul air. As, however, the means adopted are artificial, great delay would ensue should the apparatus be damaged by the enemy, or should any accident befall it.

To obtain greater certainty in this, it would seem more practical to obtain natural ventilation, and this can be effected, if as soon as the head of the gallery, or a point not far distant from it is reached, the air in the gallery is connected with the air outside by means of a shaft, as a current of air is then immediately established. In peace time, such a course would present no difficulties, as boring or digging a shaft from above would be possible; but in presence of an enemy, such a proceeding would not be practicable; and, if it were, it would not be advisable, as showing the enemy the existence of mining galleries, and pointing out their exact position. The work should therefore be carried out from below, working upwards. Boring would certainly be sufficient if borers of 6 inches in diameter could be used; but such not being available, or the ground being stony, the boring would be difficult, if not impossible. To meet this case, a shaft is advisable, although it may appear an unnatural thing to construct a shaft from below, upwards, it never having been done as yet, and seeming a very dangerous operation. Supposing, however, the construction of such a shaft to be possible, it would be very useful, and steps could always be taken to prevent an enemy from passing down it, besides the reasonable supposition that the glacis is under the fire of the defenders.

Whether the transverse section of the gallery be rectangular or gothic, and the frames used of wood or iron, the following method can be adopted in constructing the shaft:—

If AB, Pl. XIV., Fig. 1, be the gallery, the progress of which is stopped by reason of the accumulation of foul air at the head B, break out, near to the head on the left or right, a branch gallery of inferior dimensions to the original one, and at right-angles to it, for a length of about two fields, C and D, in the usual way, observing only that the planks composing the sheeting of the sides in the field D should be rather longer than the field itself, projecting a little beyond it. This done, begin to construct the shaft, observing *strictly* the following principle: *dig away the ground in curved forms progressively*, as shown by the dotted lines in Fig. 2, till there is obtained at the bottom a space shown in Fig. 3, and at the top a cupola of considerable height in proportion to its diameter (Fig. 2).

To facilitate the digging, short miners' tools of the common kind should be used. This digging must be carefully and gradually done, and should never be hurried. The ground being always damp, there is sufficient cohesion even in sand or gravel to admit of the cupola being obtained. As soon as there is sufficient room in the lower part of the shaft, line it by means of a drum, leaving a small entrance towards the branch gallery (Figs. 4 and 5).

This drum is in four parts, of wood or iron, brought in separately, and when in the right place connected together by nails or screws, *a*, *a*, Fig. 6 and 7. Now begin the normal work, *i.e.* the rising of the cupola, which is done by means of a bifurcate lance (Fig. 8). This instrument should be placed in the middle of the shaft, its point touching the highest point of the cupola, and should admit of its handle being lengthened as the cupola rises in height. If it is driven upwards and turned at the same time, the earth falls of itself, and the natural cupola gradually rises. Then at every foot of height, bring into the shaft portions of a drum to line the sides all round (Fig. 9), and continue this work till the lance passes through the surface of the ground (Fig. 10). At this moment, it need scarcely be said, the foul air rises by reason of its higher temperature, and a beneficial current is produced. To line the upper parts of the shaft, the drums should be of inferior diameter, and should be made of a conical form, gradually diminishing in diameter up to the last one, which should be higher than the rest, and made in two pieces only (Fig. 11).

To protect the men working in such a shaft from falling earth and stones, thin planks should be placed on the top of each drum as it is placed in position, and covering two-thirds or three-fourths of its area, the centre one being cut out in the middle to allow of the lance being worked (Figs. 12 and 13).

When too much earth has accumulated on the planks, interrupt the work, and throw down the earth to the bottom, from whence it should be removed by another man into the gallery. The great secret of the whole thing lies in maintaining curved forms during the excavation, and on the cupola being kept as high as possible in proportion to its diameter.

Trials with 7 lbs of gunpowder exploded at the head of gallery AB, Fig 1, showed that all the smoke went out by the shaft, and that in seven minutes' time the air in the gallery was quite pure.

It might be urged that the enemy could drop shells or other explosives into the gallery through the shaft, but it is here supposed that the glacis is still under the defenders' fire. Besides which, the top of the shaft would be hardly perceptible at a short distance; and if preventive measures against the entrance of shells be deemed absolutely necessary, an iron grating might be put in the branch gallery, and the bottom of the shaft deepened to form a shell trap.

The first shaft of this kind was made at Verona in 1858, by (now) Captain Tilzer, of the 7th Battalion, Engineers, on the author's plan, and another at Venice, at 1859. The soil in the first case was gravel mixed with sand (virgin soil); the frames and drums were of wood. At Venice, the ground was mud reclaimed from the Lagoon. In each case it was found that it was only necessary to use the lowest drum, the lance being altogether dispensed with, and the ordinary tools used. The possibility of constructing shafts in a manner so diametrically opposed to the method universally adopted, shows that there is no direction in which a military miner may not work, and it results therefrom that the miner who is thoroughly up to his work must feel a great superiority over his adversary, who would be much alarmed if suddenly called upon to do similar work without having had previous experience of it. In making shafts on this principle, the officers have to exert their authority to compel the men to use the linings, so confident do the latter become in the natural strength of the construction.

T. H. A.

PAPER VII.

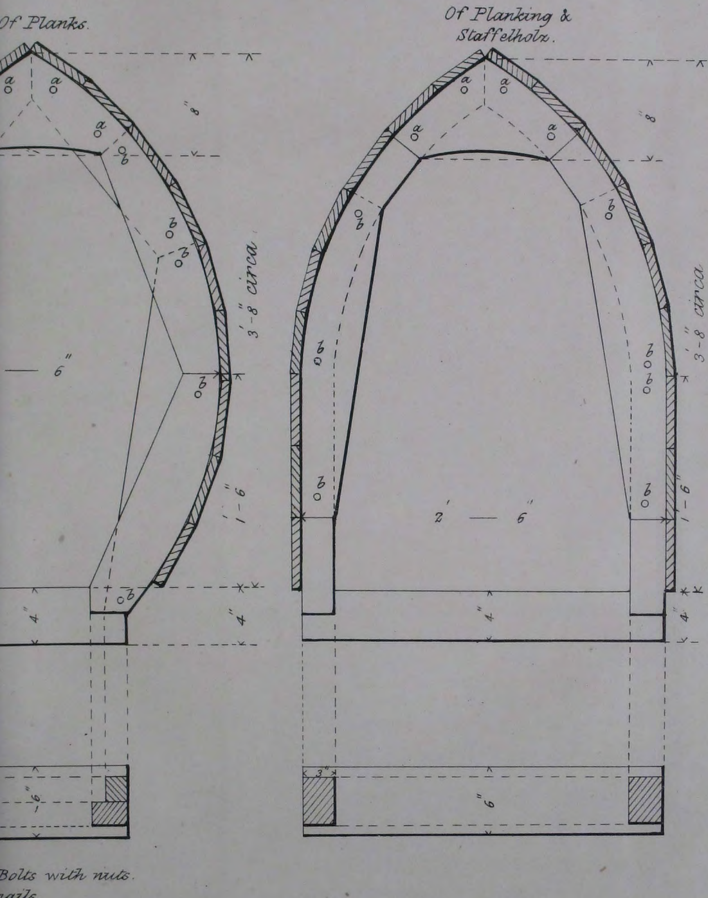
ON THE REPAIR OF A BREACH IN THE BANK OF THE WEST JUMNA CANAL AT JUTTOWLAH, PUNJAUB.

BY LIEUTENANT L. K. SCOTT, R.E.

On the 28th July, 1870, the West Jumna Canal burst its banks at a place called Juttowlah, 21 miles from Delhi.

The breach, which was 20 ft. wide, had at one time during the day been very nearly closed by the coolies, under the native overseer; but the work was, unfortunately, carried away. It had been again closed to within 6 ft. or 8 ft. when the writer reached the spot late at night. It was hoped that this small remaining gap would be completed without much difficulty. A double row of piles was commenced to be driven as straight across as possible, and also in front of, and close against, the sides of the newly repaired portion of the bank, to act as a revetment, but shortly after the commencement of this work it was found, much to the writer's surprise, that the water was actually flowing under

SMALL SIZE.


Of Planks.
Of Planking & Staffelholz.
8"
3'-8" circa
6"
1'-6"
4"
2' — 6"
3"
6"
Bolts with nuts.
nails.

V

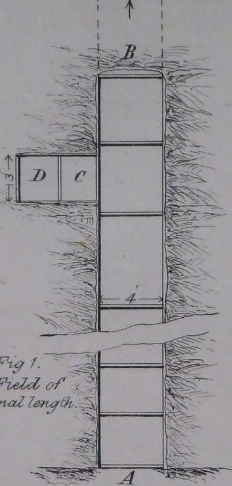


Fig 1.
D. Field of
normal length.

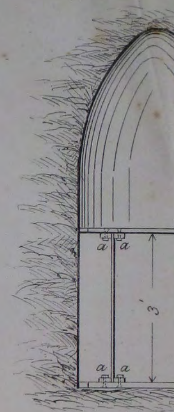


Fig 5.

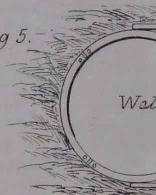
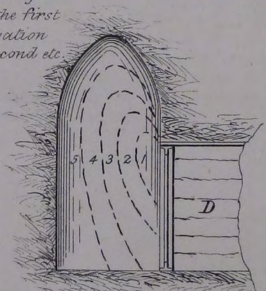


Fig 2.
1 is the first
excavation
2 the second etc.



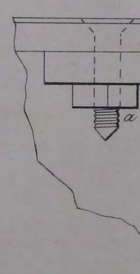
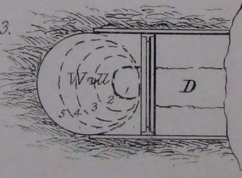


Fig 3.



the junction of the old and new bank, although, as yet, without any appearance of a breach; this immediately put an end to the hopes of effecting a close that night. On enquiry, it turned out that the overseer had been trying to repair the breach by throwing in large boughs and branches of trees, pinning them down with piles and throwing earth over them as fast as possible. This explained everything; for he had thus been gradually reducing the flow through the breach by making it pass through a good underground fascine drain. To go on with the work under these circumstances was hopeless, and it was, therefore, stopped for the night.

Next morning it was found that the previous day's bad work had been carried away, and that the breach had been enlarged to 61 ft. With such a formidable breach to deal with, the writer, at first, felt somewhat perplexed as to how to proceed without any ready made materials to be had, with the exception of a few piles cut for the previous day's work, and without proper tools to supply them.

Of course, the most natural and simple way of repairing the breach would be to cut off the supply of water at the head works (some 50 miles distant), thereby draining the canal, and to reconstruct the embankment; but, unfortunately, this was impossible, because an accident had occurred there two or three days previously, part of the works having been carried away by the floods which entered the canal and caused this very disaster. The second and only method for reducing the amount of water, under the circumstances, was by opening all the sluices of the ragbahas* and watercourses. This latter was not advisable at this season of the year, and could not be done except under most urgent conditions, because it was ascertained from the farmers that their crops had been saturated with water, and that further saturation would injure them. As Government would have to pay for the damage in the event of this course being adopted, it was determined to employ it only as a last resource. Seeing that this large stream of water had already been flooding the ground for miles for two days, and that it must finally have run into the natural drainage of the country, most probably all the injury had been done that was likely to occur. Four trustworthy men were, therefore, despatched to trace its course. These reported that it was following the natural drainage of the country into a jhiel; that the damage done was not very large; and that it was not likely to increase. In the meantime, all the coolies, 200 in number, had been told off to their several duties, viz.: to collect large quantities of earth and sods on both banks, as close to the edge of the breach as possible; to hew trees, and split them into piles; to make rammers, mallets, grass rope, &c.

The first thing to be done was to divert the current from running into the breach, so a tree was felled on the up-stream side of the bank, which was made to fall in a direction of about 45 deg. down-stream, as shewn in the plan, (Pl. XV.,) and pieces of wood were thrown into the water to find where the diverted current turned into the breach; here some large boughs were placed.

* A ragbaha is a chief watercourse, about 10 ft. broad at bottom, from which small watercourses flow for irrigation purposes.

These were found of the greatest service, for in about six hours' time, 2 ft. to 3 ft. of silt were deposited under them. At the same time, a large number of men were employed in thoroughly clearing the foundation for the new embankment of all the branches and piles placed there on the previous day; this proved a very laborious task, lasting nearly two days. To protect the banks from further destruction, piles were driven on both sides of the breach, extending 6 ft. into the stream, at a distance of about 9 ft. from the edge; these formed the figures marked I in the plan, as the first day's work. These spaces were filled with clay and earth; and in order to prevent the earth being washed away between the crooked and shapeless piles, large bundles of grass 6 ft. long and $2\frac{1}{2}$ ft. in diameter were placed outside the piles, and kept there by men standing upon them. Similarly, the remaining portion of the work was performed, as can be understood from the plan, where the numbers shew the work of the respective days—the first two days consisting of 12 hours each, and the third of only six hours.

It will be observed that the small triangle and the space in the centre of the dam was water, and not filled up with earth, because it was thought that the work might be completed by placing a great number of bundles of grass outside, and by drawing the heaps of earth gradually towards each other from both sides. This plan succeeded, and formed the skeleton of the embankment, as shewn in plan. The operation was performed by placing men side by side in the water, parallel to, and facing each side of, the breach, and by making other men draw the mass of earth against them; and by this means a great deal of the earth was prevented from being washed away. The breach was thus closed, without completing the dam, in thirty hours. While the earth was being dragged and thrown in, it was thoroughly rammed by 24 rammers. The slope of the bank was made at an angle of 45 deg., and sods, 1 ft. 6 in. by 1 ft., were laid, header and stretcher to revet it. The whole work was perfectly sound and thoroughly executed. All the piles were then taken up, and the canal cleared.

Estimate.

		R. a.
61·33 ft. × 21 ft. × 7 ft. = 9005·5 cubic ft. of earth-work	at per 1000, R21 4a. 2p.	191 3
400 stakes, about 10 ft long	at per 100, R26 1a. 7p.	104·41
Grass cutting		4 34
47 seers (= 2 lbs.) of Oil	at 4a.	11·12
80 seers of Sugar*	at 1a.	5 00
Total		R316·84
Deduct 300 stakes returned into Store, at about		60·00
Total cost of Repair of Breach		R256 84

or, £25·684.

* The sugar was given to the coolies as an incentive to them to work hard.

Explanation of plan adopted.

The reasons for making the dam into the stream were :—

1.—That it was necessary to preserve the alignment of the canal bank.

2.—That it was easier to keep the piles in their places and to drive them, than if they had been placed close to the edge or within the breach, on account of the great scour, the level of the country being about 6 ft. below the level of canal bed.

3.—That it would have been next to impossible, with the means at hand, to have driven a double row of piles straight across the shortest width of breach, and when driven, it would have been much more impossible to have dragged in sufficient earth to form the dam, on account of the uneven height of the piles. This form for the dam proved very advantageous, for as soon as a partition was completed, such as ABCD, it was very easy to draw a large mass of earth into it from the bank, and to remove it as soon as the breach was repaired. CD should be at right-angles to the direction of the current, and long enough to intercept the sods of clay washed away from the front row of piles.

Recapitulation.

When a breach occurs in an irrigation canal, where no ready made materials are at hand :—

1.—Find out the course the flood has taken, what damage it has done, and whether it is likely to increase.

2.—Remember that whatever damage is done to crops, &c., and cost of repair of breach, have to be paid by Government ; and regulate the method of stopping it, accordingly.

There are three conditions under which a breach may have to be repaired:—

(*a*.)—When the canal can be drained by shutting off the water at the head works, and by opening all the ragbahas and watercourses. This will be done without piles in a very short time.

(*b*.)—When only the sluices of ragbahas and watercourses can be opened to reduce the depth of water in the canal, which can be carried out if no damage will be done to the crops, or if the damage likely to be done by the flood will exceed that done to the crops. This will require piles, &c.

(*c*.)—When neither of the foregoing can be done.

Suggestions for repair of breach under the condition (*c*) :—

(1.)—Divert the stream of the canal from the breach by artificial means, such as by felling trees into the stream.

(2.)—Collect large heaps of earth (about double what may be required to fill the gap, to allow for the scour) close to both edges of the breach.

(3.)—Drive the piles in such a direction into the stream that there may be the greatest amount of cover behind them, and that when driven the earth may be easily drawn or thrown among them to form the dam.

(4.)—Drag the earth in in large masses, very gradually, from both sides, and make the men, if necessary, draw it against themselves, thereby forming a human revetment; this mode is the only chance of joining the embankment together with an uncompleted dam.

(5.)—No leaves or branches, on any account whatever, are to be thrown on the foundation of the new embankment, because this will never make sound work, and there will be endless trouble in getting rid of them, should the bank (which is most probable) be breached again in the same part.

Materials, &c., employed.

Number of coolies—200.
Tools—Axes and circular handsaws.
Materials—Trees split up into piles, sods, earth, bundles of grass, grass rope, rammers, mallets.

	Feet.
Breadth of breach	61
Depth at places	7
Breadth at top	21
Depth of water in canal when breach occurred	5·5
Usual depth	4·4

(Increased depth due to an accident at the head works from floods.)

Difference of level between bed of canal and level of country, about 6 ft.

Cause of the Breach.

There are three ways in which it might have occurred.

1.—By the water topping the banks.

2.—By deficient section in the bank.

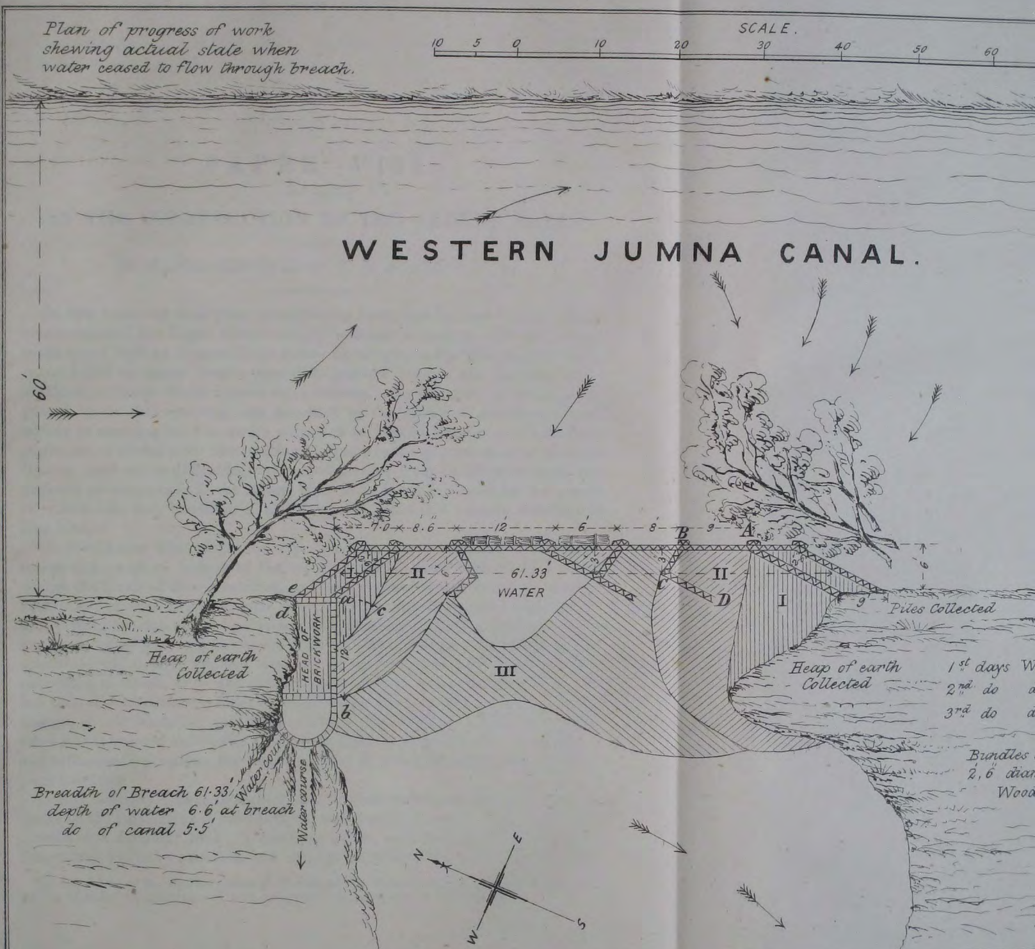
3.—By vermin holes, which would render the bank weak.

The water did not top the banks.

The section was strong enough, having withstood the pressure for years; therefore, it must have been occasioned by vermin holes combined with faulty construction in the head of the watercourse. A rat hole is sufficient to cause a breach during floods, from the extra pressure of the water, which gradually works its way through.

The faulty construction of the head is apparent in the plan: *a b* is a straight wall right through the bank, which gives a line of great weakness, particularly when the expansion of the clay, from the great differences of temperature, is taken into account. The head ought to have been constructed with wing walls, *ac*, *cd*.

L. K. S.



Plan of progress of work shewing actual state when water ceased to flow through breach.
SCALE.
10 5 0 10 20 30 40 50 60
WESTERN JUMNA CANAL.
60'
7·0 8·6 12' 6' 8' 9
A
B
C
D
I
II
III
61.33'
WATER
HEAD OF BRICKWORK
Heap of earth Collected
Heap of earth Collected
Piles Collected
Water course
Water course
Breadth of Breach 61·33'
depth of water 6·6' at breach
do of canal 5·5'
Bundles
N
E
S
W

PAPER VIII.

ON THE CONSTRUCTION OF THE ALBERT HALL.*

BY MAJOR-GENERAL H. Y. D. SCOTT, C.B., &c.

On first receiving from your committee an invitation to read a paper on the construction of the Royal Albert Hall, I hesitated to comply with the request made to me, both on account of the numerous calls upon my time, and the reluctance I felt to appear before your distinguished body in the character of an architect, a title to which I make no pretension. On reflection, however, it appeared to me that one who had benefited by the advice of members of your society in carrying out the duties entrusted to him so largely as I have done, ought not to shrink from contributing his quota to the general stock of information on constructive difficulties and expedients, or from enabling so novel and gigantic an experiment as the Albert Hall to be freely criticised for the benefit of others who may hereafter be called upon to plan and execute buildings of like kind.

On considering what might be expected from me, it appeared to me that a complete descriptive memoir of the work would be more than could be read within the limits of time prescribed, and that my best course would be to select such points of it as exhibited some novelty in practice, or involved some important principle which might be elucidated by discussion. Before, however, entering upon my subject, it is necessary that I should premise a few words on the conditions which were imposed upon me in carrying out a work, the general conception of which, as to size and arrangement, was originated by others. It is a task of some delicacy, under such circumstances, to avoid, on the one hand, charges of self laudation and depreciation of the original design, and on the other hand, to avoid exhibiting a too morbid desire to escape such imputations and reference to questions, the free discussion of which should be the object of your meetings.

In this difficulty I have thought it best to place before you the drawings and model of the building as designed by the late Captain Fowke. This model was completed in January, 1865. These were put in my hands as the basis of the design that was to be executed, and without hesitation, and in the reliance that

* A Paper read at the Ordinary General Meeting of the Royal Institute of British Architects, held on Monday, the 22nd January, 1872, and printed by permission of the Council.

you will interpret my motives generously, I invite attention to the modifications I have ventured to make, and to my reasons for considering them improvements. It is, however, necessary that I should make it clearly understood that the model and drawings exhibited to you as Captain Fowke's, embodied only his first rough ideas on the subject, and that what the building might have become if he had lived to mature his design cannot be fairly judged of from them. The model of the interior and the exterior elevation are so little in accord, indeed, that they cannot be said even to belong to the same structure. That this was so, naturally left to me the greater latitude in re-modelling his work, but of this latitude I always hesitated to avail myself, until I found that my opinions were fortified by the approval of others, For such reluctance to make changes I claim no praise. It is simply due to the fact that whilst I have always considered that my late brother officer and friend was naturally gifted with unusual architectural and constructive ability, I have not had equal confidence in my own. I have only to add to this introductory explanation, that the original notion of such a hall was the offspring of the fertile brain of Mr. Henry Cole. Pl. XVI., Fig. 1, is an enlargement of a pen sketch by him which was sent from Amiens, 8th November, 1863, to Mr. Gilbert Redgrave, as the first idea of the section of a building to seat 17,000 persons.

The data prescribed for my guidance were these :—

1. That the building should be of amphitheatrical form, and should seat in ease and comfort 6,000 or 7,000 persons.
2. That the interior accommodation for an audience should consist of:—
   (*a*) An arena which might occasionally be used for a promenade or exhibition.
   (*b*) Some ten or twelve rows of seats above the arena arranged in the form of an amphitheatre.
   (*c*) Two or three tiers of boxes above the amphitheatre seats.
   (*d*) A great gallery open to the interior of the hall, running round the building between the interior and exterior walls, and top lighted.
3. That the entrances and exits should be arranged like the seats on the plan of the old Roman amphitheatre.
4. That the façade should be of red brick and terra cotta dressings.
5. That the whole expense of the work should not exceed for building works and expenses connected therewith, £175,000.

With these instructions, I found myself in the possession of an advantage such as probably no architect ever yet enjoyed, or probably would care to enjoy. I was to have the advice of a committee, and this committee consisted of the following eminent architects, artists, and engineers, viz. :—Sir Wm. Tite, Sir M. Digby Wyatt, and Messrs. Fergusson, Fowler, Hawkshaw, and R. Redgrave, R.A. I take this opportunity of publicly thanking these gentlemen for the valuable assistance they rendered me. Whilst they showed not the slightest desire to do my work for me, they were ever ready, collectively and individually, to help me to do it myself.

At a preliminary meeting of the Committee a question was raised on the first of the above data, which, it is to be hoped, will be fully discussed this evening. It was suggested that instead of the form of the Roman Amphitheatre, that of the Greek Theatre should have been taken as the model. The general form of the amphitheatre was, however, considered to be one of the fixed conditions of the problem, but it is a fair question for debate whether the results give reason to suppose that any other shape would have enabled an audience better to hear varied musical performances, or have afforded a more imposing effect. The general form proposed by Captain Fowke for the plan of his interior had semicircular ends, joined by almost parallel sides, as shewn in Pl. XVII., Fig. 3. The plan executed, shewn in the same diagram, is a very close approximation to an ellipse, and is formed of arcs of circles struck from four centres. By this means the difficulties in construction which the varying curvature of the ellipse would have entailed, have been avoided. The major and the minor axes between the walls which carry the roof, are as 11 and 9 nearly. This form was determined on after careful consideration of the following experiments, opinions, and facts.

The experiments of Saunders, described in his well-known work on Theatres, showed that a person reading from a book could be equally well heard in the still open air at a distance of 92 ft. in front, 75 ft. on each side, and 31 ft. behind. Sir C. Wren's distances for the same position with reference to a speaker having a good delivery, are, for an enclosed building, 50 ft., 30 ft., and 20 ft. The distances proposed by Captain Fowke were 204, 82 and 76 ft., and in the Scala Theatre at Milan, the largest and the most perfect lyric theatre existing, the distance from the curtain to the back of the boxes in front is 105 ft., and the greatest half width of the auditorium $43\frac{1}{2}$ ft.

It will be observed that the distances for equally clear hearing in the open air are, according to Saunders, as 5, 4·5, and 2, for a person standing in front of, at the side of, and behind the speaker, whilst Wren estimates the same distances in an enclosed building to be in the proportion of 5, 3 and 2. Captain Fowke apparently attributed much more influence than Wren to the effect of side walls in carrying the wave of sound forward, for his distances are as the numbers 5, 2 and 1·8. The distances actually adopted in the case of the hall are 163 ft. in front, $92\frac{1}{2}$ ft. for the half width at the broadest part, and 56 ft. behind the position of a solo singer. These distances are very nearly in the proportion of 5, 3 and 2, the proportions given by Wren. Including the width of the picture gallery, the distances from the singer in front is 186 ft., and the half width 116 ft.

The plan of the hall is shown in Figs. 3 and 4, in juxtaposition with the forms which would have been given on the four above-mentioned conditions, and this, in connection with Figs. 1 and 2, enables the modification of Captain Fowke's plan, both as respects size and shape, to be estimated. The main grounds on which this modification was made are sufficiently apparent, but the alteration also afforded the opportunity, owing to the greater width given to the building, of introducing the balcony, which was not a feature of Capt. Fowke's design, and which provided accommodation for 2,000 seats of a cheaper description, with a sacrifice of 800 seats in the amphitheatre and arena. The increased curvature of the sides also had collateral advantages as respects the stability of the roof, and my committee of advice agreed to the advisability of making the change on general, if not on architectural, grounds. Although, from certain points of view, something of the grandeur of Captain Fowke's proposed arcade may have been sacrificed, more than the equivalent of this loss has been, to my own mind, gained by giving to the arcade a visibly solid wall to stand on from whatever part of the interior it might be seen. A reference to Figs. 1 and 2, which contrast the two sections, will enable this question to be judged of. The total length from outer wall to outer wall, as executed, is 266 ft., and the breadth 232 ft. With reference to the general shape of the interior, I have only to add that the length, breadth, and height do not materially differ from the proportion 5, 4 and 3, though this would scarcely be judged to be the case from the appearance of the building. The actual figures are a length of 219 ft., a breadth of 185 ft., and a height of 136 ft. I have generally found that the height has been much over-estimated by visitors. This is probably due to the contraction of the floor by the amphitheatre arrangement of the seats. The central portion of the ceiling in the original model was flat, as may be seen. The plan adopted of following the arched form of the lower members of the ribs of the roof with the glazing was simpler, and though it appeared to threaten greater danger of echo than a flat roof, from the concentration which it would give to reflex waves of sound on focal points of the auditorium, it afforded a better opportunity for introducing a velarium, which, whilst it acted as a sunscreen, imparted to return waves that divergence which was manifestly to be desired.

It has been assumed by some critics of the acoustics of the Hall that the velarium was an invention introduced to cover a defect found out only by experience. But its expediency, with the reasons for and against it, was freely discussed in the architectural papers in the beginning of 1869, when the roof was not yet fixed. As early as December 12th, 1868, the "Standard" speaks of it, and on April 26th, 1869, the "Globe" informs its readers that "underneath the dome it is proposed to suspend a velarium, to act as a sunshade, and to deaden or prevent the reverberation and echo." It was, indeed, too natural an idea that a building so resembling a Roman amphitheatre should be covered with a velarium, to allow the question to be overlooked. This plan of obtaining a satisfactory ceiling was mentioned to me at a very early period by Sir W. Tite, but it is really to Mr. James Wild that I am indebted for urging upon me that it was the only appropriate way of covering the building, until—adverse criticism notwithstanding—I determined on adopting it. Mr. Wild's idea, however, was that there should be no coving, and that the velarium should be attached to the vertical walls of the structure, forming, in fact, the entire ceiling underneath the double glazing; but it was thought that it would be impossible to give through the scallops of the velarium (owing to the forest of iron ribs, purlins, and ties of the roof) anything like the effect of the sky which one might expect to see, and there was a fear that something more substantial than a mere covering of cloth underneath the glazing would be necessary in this country to impart an idea of security and comfort. Mr. Wild's proposition would moreover have rendered the lighting by gas more difficult, and, by the omission of the coving, have deprived the auditory in the balcony of a sounding board, from the proximity of which a strengthening of the sound waves was expected.

I may remark, in passing, that a great collateral advantage, in point of artificial lighting, is gained from the white reflecting surface of the velarium. Large quantities of light are absorbed at night by a dark glass roof.

In considering the mode in which the interior of the walls of the Hall should be finished, three courses were open, each of which had advocates whose opinions merited consideration. The first course was to discard resonant materials as far as possible. Those who think that this is the right course argue that, after the sound has reached the ear by direct radiation, the sooner it is absorbed the better, and that any degree of resonance from the walls is detrimental to musical effect. A second course was to finish the walls with hard well polished plaster, and to lay the floors with tiles. This was the opinion of Mr. Willis, who built the organ, and whose voice in the matter necessarily demanded attention. A third course was to line the walls with a resonant material, and wood was determined on for the following reasons :—

1. It was believed that sound in its utmost purity is heard in still open air, and that this may be due, not only to freedom from disturbing reflections, but also to the absence of causes interfering with its free transmission, and checking vibrations isochronous with the vibrations of the atmosphere, such as would be interposed by draping the walls.

2. It had been noticed that tiled floors gave rise to sharp, irritating reflections of sound, such as may be perceived in the centre refreshment room of the South Kensington Museum.

3. The buildings most remarkable for their acoustic properties have all been lined with wood. The celebrated theatre of Parma, in which a speaker could be heard, when speaking in a low tone of voice, at a distance of 140 ft., Her Majesty's Theatre in the Haymarket, which was destroyed by fire, the Surrey Music Hall, which shared a similar fate, and the Theatre of the Royal Institution, all especially successful buildings in point of sound, were lined in this manner.

4. It is a generally received opinion that a room sufficiently non-resonant for

a speaker with ordinary rapidity of utterance, and without modulation of the voice, is too dead for musical purposes, which were to be the chief purposes of the Hall, and the resonance from wood is universally admitted to be more beautiful than that obtained from any other material.

5. The correction of undue resonance is easily accomplished by draping, but it would be costly to impart resonance to a building deficient in this respect.

Acting on these considerations, and the results of my many conversations on this subject with Mr. Roger Smith, whose information on matters of acoustics was always at my service, the whole of the high wall behind the orchestra was covered with $\frac{1}{2}$-in. battens carefully tongued together with an air space of $\frac{3}{4}$-in. between this wood lining and the wall. The whole of the wall of the picture gallery, with the exception of the pilasters, which divide the wall into bays, was lined in a similar manner. The coving of the roof, with the exception of the cornice, which is of fibrous plaster, and that portion of it which is not of glass is also of $\frac{1}{2}$-in. battens tongued together, and covered on the upper side with canvas stretched and glued upon it. I attribute the fact that the most delicate musical sounds are distinctly audible, even at a distance of 186 ft. from the performer, to be due, in no small degree, to the existence (near the most distant listeners) of the wooden sound-boards with which the Hall is lined. There is one other point in the acoustics of a building of this immense size to which I should wish to draw attention. Loud noises must produce a distinct return sound, though it may be a slight one, from distant walls, however covered. If any one of my hearers will, on the next still day he finds himself in one of our parks, clap his hands, even with leafless trees in front of him, he will obtain an echo, the audibility of which, if he has not performed the experiment before, will surprise him; or if, when on one side of a valley, although the slope opposite to him has no great inclination, he will make a sudden noise, he will obtain a reflex sound, the intensity of which will also be very considerable. If, again, in the neighbourhood of two buildings at different distances from him and in different directions, but exposing surfaces towards him capable of returning distinct echoes, he will listen for the echo from one building, he will hear this only, and then on listening for that from the other he will hear that one only, and yet, by an effort of attention, he will be able to succeed in hearing both distinctly return the sound he makes. And, lastly, if, as I have done, he walks about making experiments and listening for echoes, he will raise a ghost which he will find it very difficult to lay. The ear, in fact, becomes painfully susceptible of impressions of this description, and listening for echoes had much to do with those which were once complained of in the Albert Hall. We now no longer hear of them, because people go to listen to the music and not for reflex sounds, which, doubtless, so far as they are appreciable, injure it. I am not, of course, speaking of such distinct echo from the roof as was heard in the arena from the Prince of Wales' voice on the opening day. This was occasioned by the reflection of the waves of sound from the convex glass roof, which the velarium was too thin to intercept, and which has been remedied by calendering and filling up the pores of the cloth of which the velarium consists. I speak of the reflex sound which, as I assert, must be returned audibly enough to be heard, if listened for, from distant surfaces, even if clothed with persons, when the loudest percussion notes of an orchestral performance occur. This is an inherent defect, so far as it goes, of very large buildings. On the other hand, it is not unreasonable to suppose that delicate passages of music are heard in greater purity in very large than in small rooms. The removal of the disturbing surfaces to a distance from the source of sound may render reflections from them inappreciable.

There is one other point in connection with the acoustics of the building which I think is worthy the attention of architects. It is a matter of common observation that musical sounds often set up a vibration in the sound-board of a piano, glass drinking vessels, and similar resonant objects. Manifestly an interval must elapse between the actuating sound and the sympathetic response, and if the wooden coving of the Hall or the lining of the picture gallery respond to Sir Michael Costa's big drums or the loudest notes of his trumpets, we should, from this cause also, obtain, in some positions, an echo-like repetition of the original sound at an appreciable interval. It is an interesting question how far the effects of the loudest musical passages have, by the resonance of the lining of the Hall, been sacrificed in obtaining excellencies as respects those of greater delicacy, for which it was predicted that the Hall would fail.

An important modification of the original design has been made in the arrangement of the staircases. It was originally intended that the space between the inner and the outer wall should be completely filled with stairs and landings, the one over the other, running spirally round the building, and all having their exit in one common corridor. Instead of this, a plan has been adopted which gives to each staircase, or pair of staircases, an exit into a separate crush room, thus enabling visitors in different parts of the building to be kept separate. Arrangements can also be made in some cases for using particular stairs for one or the other part of the building; but assuming the normal occupation of the different parts by a very full house and the ordinary appropriation of the staircases, the provision made is at the rate of one staircase to 200 persons for the boxes and arena, and one staircase for 500 persons in the balcony and picture gallery. The amphitheatre has one exit for every 250 persons. Each of these exits is 9 ft. wide. Sixteen of the staircases are 6 ft. 6 in. wide and two of them 4 ft. 6 in. wide. There is also a lift which can convey about 15 persons at a time to any of the floors but the basement, and a space left for a second lift of equal capacity. The lift is worked by hydraulic pressure, and was executed by Messrs. Easton and Amos. The corridors, crush rooms, and staircases together, afford sufficient space for the whole of the visitors that the auditorium and orchestra will contain, to be in movement at once without jostling each other.

The result of this ample provision of corridors and staircases is that the auditorium empties itself in a few minutes. Full advantage, however, of the numerous exits of the building cannot at present be made available to nearly the full extent of which they are capable, but it is in contemplation to make roads both to Exhibition and Albert Roads from the south-eastern and south-western sides of the Hall, and a Bill will be introduced this Session for connecting the Hall with the South Kensington Station by a Pneumatic Railway. The Hall, at the present moment, provides accommodation for the following numbers in its different parts :—

In the Orchestra	1000 singers.
" "	200 instrumentalists.
Arena	810
Amphitheatre and Loggias ..	1642
Boxes	830
Balcony	1783
Organ Gallery	100
Picture Gallery	2000
Total	8365 persons.

By putting the seats in the arena closer together, and by filling the gallery with raised seats, this number could be increased to 10,000 persons, a formidable number to provide for, in these days of cabs and carriages, whatever be the facilities for entrance and departure. The sum of the widths of the external doors for these 8,365 persons is divided between twenty-five entrances, of which that from the Horticultural Conservatory is 16 ft. wide, and all the others 4 ft. 6 in. wide, being one foot to every sixty-four persons.

Before leaving those parts of the arrangements which have reference to the accommodation of an audience, I should mention that the allowance for each amphitheatre seat is 3 ft. by 2 ft., the chairs turning on an axis, both to allow greater freedom of passage for reaching the inside places, and to enable persons on the sides of the building to turn towards the singer. In the balcony the allowance is 2 ft. 6 in. by 1 ft. 8 in., and room for passage is afforded by the seats turning up and allowing their occupiers to stand between their supports. In the arena, boxes, and gallery the seats are not fixed and can be changed according to the requirements of the entertainment. It will be observed that the part of the two upper tiers of boxes which is supposed to be occupied by persons listening to a performance, projects some distance beyond the compartments above them. This arrangement was made with the idea of bringing their occupants more into view, and thus adding to the imposing effect which is given by a great number of well dressed ladies.

The roof is perhaps the most interesting of the constructive features of the building. In its first conception I had the advantage of the counsels of Messrs.

Fowler and Hawkshaw, who were members of the committee of advice, and I was also assisted by the engineering ability of Messrs. Grover and Ordish, to whom was entrusted the preparation of all the drawings as well as of the calculation of the strains on which they were based.

It would be impossible on this occasion to give to this subject the attention which it merits, and I must confine myself to a reference to the general principles and considerations on which reliance was placed for the security of the structure. It is well known that disaster was prophesied here as well as in those acoustic properties of the Hall which have proved its greatest success; and in each case, even in the absence of such prognostications of failure, there was enough in the gigantic nature and novelty of the undertaking to cause some anxiety.

In the diagram on the wall you will see the first rough notion of the roof, which was left to me by my predecessor. As you will observe, it was supported by buttresses resting on the two walls of the building; but to have taken advantage of this means of receiving thrust it would have been necessary to have accepted an unequal division of the bays of the outer wall, as shown in Captain Fowke's elevation, for it is manifest that if the columns supporting the roof in the interior of a structure are arranged on an ellipse, the prolongation of radii through these columns to an outer wall will not equally divide this wall if it be an ellipse parallel to the first one. Some other means than buttresses, therefore, had to be devised for securing the wall which carries the roof against its thrust. The expedient adopted for this purpose was a wrought iron wall plate, of girder shape, resting with its web on the wall, and supporting the ends of the roof principals. At the first blush there might appear to be danger in trusting to the varying rates of expansion of brickwork and wrought iron in a continuous girder of nearly 700 ft. in length, but it was considered that even if the expansion of the iron caused an irresistible strain on the brick arches which joined the piers for supporting the roof, the elasticity of the piers would be sufficient to take up the expansion of the wall plate, and no further damage could result than minute and probably invisible fractures through the crowns of the arches. As a matter of fact, we thought that in one arch we did detect a fracture on the inside, but could not trace it on the outside. The clerk of the works thought that he had detected fractures in three other arches, but he was unable again to find them to point them out to others.

The next question was how far a girder wall plate, of reasonable weight, could be trusted to take the thrust of the roof load and the strains arising from wind. Of course, if the plan of the building had been circular, the strain on the wall plate, independently of strains from wind, would have been equal at all points, but with an elliptical plan the thrust of the principals of the roof, owing to the inequality of the weight of roof upon them would vary with the inequality of the two axes of the ellipse. Nevertheless, Mr. Hawkshaw counselled the adoption of simple ribs having one member only, but of considerable strength, which should carry a central curb rising and falling freely with the variations of temperature. The simplicity of this idea had much to commend it, but I was too timid to adopt it, and principals like those at the Cannon Street Station, on the trussed girder system, were determined on. The lower member, however, instead of being a simple tie-rod of circular section is made of an inverted T form to enable it to receive compression as well as take tension. By uniting, also, both the upper and lower members of these principals in central curbs, which are assisted in keeping their form by tie-rods, the principals are enabled to act either as arches or trussed girders, and thus can better cope with unusual or irregular strains.

In considering the probable stability of such an arrangement, it is to be observed that when the principals act as arches, notwithstanding the inequality of their thrusts, the strain on the wall-plate will not vary correspondingly, owing to the smaller radius of curvature at the end of the longer axis and the different angles which the lines of tension on the wall-plate therefore make with those of the thrusts. In fact, the calculated thrusts of the principals do not vary materially from those which are necessary to keep the wall-plate in equilibrium. Supposing, however, any unexpected disturbance to arise, the tendency to loss of shape would at once be arrested, for the lower members of the principals would come to the rescue and get into full work as tie-rods before damage to the walls could occur. There is another element of strength in a roof of this construction which should not be lost sight of. Each principal is equal to carrying the weights to which it can apparently be subjected, whether acting as an arch or as a trussed girder; but, if any weakness existed in a principal, it would, from the polygonal form of the purlins, receive much support before mischief was done. The purlins towards the crown must suffer compression, and those on the haunches get into tension as the crown of the roof sinks, and any other change of form would be resisted in a similar manner.

Again, the especial defect of girders of this form as respects lateral and sudden strain from wind is here in a great measure obviated, for not only is the pressure upon any particular half-principal transmitted through the purlins to its neighbours, but the movement of the central curb on which such half-principals rest will be resisted by the series of thrusts transmitted to it by the opposite radiating half-principals resting on and distributing their thrusts over a large arc of the wall-plate on the side opposite to that in which the impetus is given. The case, in fact, is almost as different from that of similar trussed girders resting on parallel walls as a wire meat-cover standing firmly on the metal ring at its base differs from a simple arch of the interlaced wire of which it is formed standing on two pieces of unconnected metal as a base.

Before leaving the question of the roof, I should mention that the iron work was all prepared by the Fairbairn Engineering Company, and that we derived much valuable assistance in modifying certain details of our original plans from Sir William Fairbairn, who was always as ready to discuss any question connected with it as if he had been personally responsible for the design.

I have little time for entering upon any constructive details, but I ought not to pass over one or two expedients of a somewhat novel kind which were ventured on. The whole of the main wall was constructed of hard Cowley stocks set in Portland cement with three parts of sand. Portland cement was also, in all cases, used for the concrete necessary to bring the gravel surfaces which were to receive the foundations to a true level, and to fill in the excavation in the clay bottom, which extended on the south and south-east sides over one-third of the area occupied by the building. The outer wall, built in bricks made by the contractor, was also brought up to the level of the shallowest footings in Portland cement mortar of the above composition; but all above this, and all the cross walls and the walls within the main wall were executed in mortar made in a mill, with one measure of grey lime previously slaked, one measure of Portland cement, and six measures of sand. The set of this mixture was sufficiently rapid to prevent any settlement taking place which might bring an undue strain on the terra cotta dressings. It also enabled the main wall to be completed to its full height, and the roof to be commenced before the outer wall and cross walls were brought up, and in no instance did any such inequality of settlement from this cause take place as to produce fracture. The outer wall was, of course, delayed for the terra cotta. Delay in the supply of this material appears to be an ever irritating difficulty in its use.

The plastering used on the interior walls merits perhaps some attention. Instead of making the lime into coarse stuff, as is usually practised, and finishing with lime or guaged putty, the grey chalk lime of the Medway was ground to a powder and made into mortar on the following system :—One quarter of a cubic foot of plaster of Paris was stirred into a bucket of water and thrown into the pan of an ordinary mortar-mill, so as to make a milky fluid of the plaster of Paris; another bucket of water or so was then added, and five cubic feet of the ground grey lime gradually added, with the addition of more water, the mill continuing in action the whole time until the pan contained a thin slip of the lime and plaster. To this mixture 30 cubic feet of sand were added and thoroughly incorporated with it, and the mortar was then ready for use. Thus treated, the lime sets without slaking, and makes what I have termed "selenitic mortar."

For the finishing coat in rough stucco, the quantity of sand was reduced to 20 cubic feet, and after the first coat was put on the wall, the plasterers could, in a few hours' time, follow on with the finishing coat. For the first coating on lath-work the usual quantity of hair, but unbeaten, was added whilst the mortar was being incorporated, and the ceilings were finished with a mixture of slip prepared as before, with one part of chalk and two parts of sand for every part of lime used in the slip.

The whole of the outer corridors, staircases and crush-rooms, and all the private and refreshment rooms round the building are, as it is termed, fire-proof, no wood being used in their construction beyond that of the doors, windows, and the wood slips used to carry the concrete and tiled floors. Probably, in the case of a fire in the interior of the Hall, the title would not be belied, for the inrush of fresh air would be so great as to keep all without the auditorium perfectly cool. Since also the audience empties itself into these corridors and crush rooms in a few minutes, there is no great likelihood of loss of life in the event of a fire occurring. As precautions against fire, hydrants are fixed at several points on each floor level, the whole being in communication with 30 tanks on the picture gallery roof, containing in all nearly 50,000 gallons of water. These tanks are supplied from a well sunk through the London clay into the chalk, in the rear of the building, and they also receive the rainfall on the large roof. The hydraulic lift is supplied from the same sources.

In the warming and ventilating arrangements I had the assistance of Mr. W. W. Phipson, who has had great and varied experience in the heating of large buildings. Coils of hot water pipes are placed in three separate air-chambers, under the arena, the amphitheatre stalls and the main corridors of the building respectively. The heated air from those in the arena ascends through the interstices of the floor; that from the coils under the amphitheatres through the risers of the steps on which the seats are placed; and that from beneath the main corridor finds its way through passages in the wall into the boxes, the picture gallery, the corridors, the refreshment and private rooms and small lecture theatres. The external fresh air is forced in by two fans 5 ft. 9 in. in diameter, each worked by a 5-horse power engine, and blowing right and left through passages provided for the purpose into the three above-mentioned air-chambers. It may also be drawn through them by the ascensional current of heated air in the Hall itself, which, when the gas is lighted, or the building warmed in cold weather, exerts an enormous force. The amphitheatre and corridor air-chambers, with their systems of coils of hot water pipe, can be together utilised for the Hall or for the corridors and private and other rooms. In order to preserve equality of temperature in all parts of these chambers, the coils of hot water pipe are divided into sections, each section having its own hot water generator, in which the temperature is kept up by a supply of steam from three 25-horse power steam boilers at the back part of the building. There are sixteen such generators, each supplying its own system of pipes with hot water and admitting of being put into action or thrown out at will. The total amount of heating surface in the various coils is represented by about 28,000 feet of 4-inch hot water pipe.

The chief difficulty in connection with the management of the warming and ventilation of such a building is the control of the inward draught when the doors are open from the ingress and egress of the audience, but by carefully attending at these times to the closing of the louvres of the upcast shaft through the centre ring of the roof, this draught can be controlled.

The conditions prescribed for the exterior were as I have said, that the façade should consist of red brick with terra-cotta dressings. The subject of terra-cotta, as a decorative building material, has been so fully treated of by Mr. C. Barry, that it is unnecessary for me to do more in relation to its use in the Albert Hall, than refer briefly to the principles which guided us in its application and treatment. The terra-cotta material was considered simply as a superior description of brick, to be used in conjunction with plane surfaces of a somewhat similar material, but of another colour. It was thought, therefore, unnecessary that the lines and edges should have the precision of stone work given them, or that the blocks should be of large size. It was further judged that delicate modelling would be out of character with a building which must be of very massive appearance, and which should depend more for its effect on the sweep of its lines than on exquisite finish. These opinions were held strongly by Mr. Townroe, to whom the Hall is indebted for the actual modelling or immediate superintendence of the whole of the modelling work, and I judged them to be correct. Many, undoubtedly, think that the modelling is too coarse, but I have been gratified to observe that the eye of the painter is generally pleased with the picturesque effect which this mode of treatment has imparted, an effect to which, doubtless, the varied and rich tints of the material itself have largely contributed.

The terra-cotta was all supplied by Messrs Gibbs and Canning, of Tamworth. The blocks for the preparation of the moulds were supplied to them by us, and the terra-cotta work was fixed by masons furnished by the building contractors.

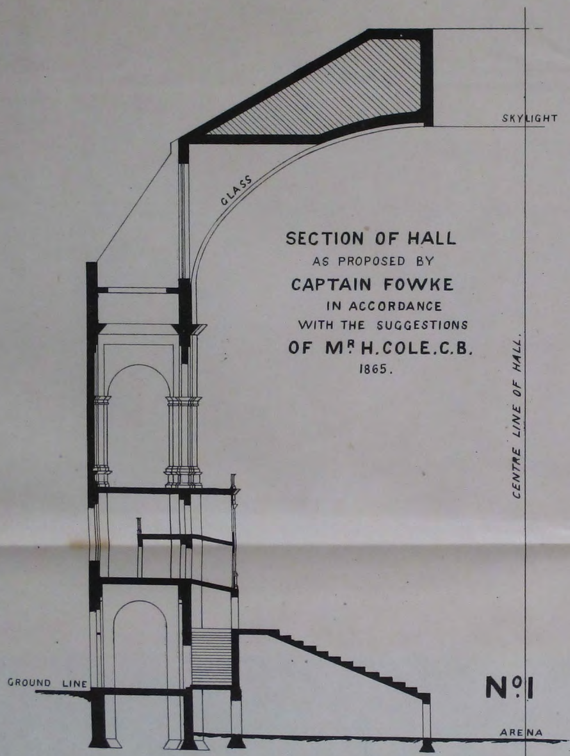
The terra-cotta of Messrs. Gibbs and Canning is prepared from fire clay without foreign admixture, and is burned at a high temperature, such as promises to render it very durable; the blocks are not made in the manner followed by Messrs. Blashfield and Blanchard, with cells which have to be filled in with concrete or grouting, but are chambered from behind, so that the brickwork of the wall can be built into them. It is necessary, therefore, in estimating the cost of fixing this terra-cotta, to allow for the extra brickwork necessary, but of course there is a saving of grouting and concrete. This system appears to me to make a better job than the blocks with the cells closed at the back.

The red bricks employed in conjunction with the terra-cotta were supplied by Mr. W. Cawte, of Fareham. They are very heavy and hard—having, if I may use the expression, a metallic looking, and slightly conchoidal fracture—are little absorbent, and are for beauty of tint unsurpassed by any bricks in the kindgom. I was indebted to Mr. Gilbert Redgrave for the whole of the work connected with the preparation of the terra-cotta, as well as for his general advice and assistance in every part of the work. Mr. Verity was charged with the preparation of the constructive working drawings.

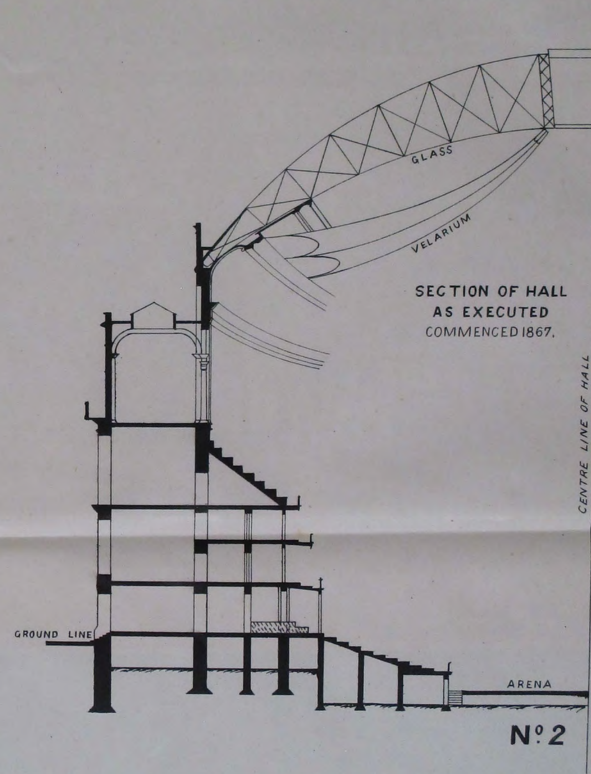
It will be observed that on the exterior of the wall of the picture gallery in the original design, the surface was broken with decorative panels of geometric design. It was suggested to me by Mr. Henry Cole that this wall gave a fine opportunity for a mosaic picture of figures which he thought should be considerably larger than life. My assistant, Mr. Townroe, on the other hand, while he approved of the notion as much as I did, was strongly in favour of reducing the figures to nearly half life size, and Mr. Gamble, who was much consulted throughout, and who was my boldest adviser in most cases of doubt, supported him. In this conflict of views, I resorted to the counsels of the weak and prudent, and adopted the middle course, which had to my mind this recommendation. The first idea of a spectator would be that they were life size, and although the apparent magnitude of the building might be enhanced by a reduction of the figures, it was better that such an expedient for producing effect should not be attempted, as the balcony immediately below it, with or without living persons standing on it, would certainly reveal the truth. On the other hand, I saw no reason to reduce the apparent size of the building for the sake of a fine mosaic picture. The figures, by the advice of some of the artists who undertook to prepare the designs, were finally made something over full life size. It was at the same time arranged that the colours should be buff upon a chocolate ground, and that the outlines should be black. These points were settled in conjunction with Messrs. Pickersgill, R.A., Marks, A.R.A., and Yeames, A.R.A. The other artists who contributed designs were Messrs. Armitage, A.R.A., Poynter, R.A., Horsley, R.A., and H. Armstead. The frieze was divided into sixteen lengths of about 50 feet each, some artists taking two or three such lengths, and the sum accepted in payment for the work was so moderate as to entitle these gentlemen to the warm thanks of all who are interested in the application of pictorial art to architectural buildings.

This valuable series of designs is exhibited this evening on your walls. They are drawn on a scale of 6 ft. 6 in. to the foot, and the task of enlarging them to the size of the proposed mosaic reproductions was entrusted to Sergt. Spackman, of the Royal Engineers, who was fortunate enough, as I believe, to make the enlargements to the entire satisfaction of the artists. He prepared small photographic negatives from the originals, and by means of a camera, illuminated with a lime light, threw an image of the required size on to a screen covered with paper, upon which the necessary outlines were then put in with black lines. Sergt. Spackman, who is himself an artist, determined, as a rule, the thickness of the lines to be used, but on this point he consulted the artists whenever he was able to do so. The thicknesses of the tesseræ employed in translating these enlarged pictures varied from $\frac{7}{8}$ of an inch to $\frac{1}{4}$ of an inch in five gradations.

It would occupy your attention too long to describe the process by which the mosaic workers produced the actual ceramic pictures on the walls of the building, and I have said sufficient to enable an opinion to be formed of the feasibility of the more general adoption of this species of mural decoration. I would only observe that the flat treatment in this case was not selected from a conviction that it is in itself superior to a treatment in relief for exterior decoration, but because the latter mode would have been very difficult or impossible, for two reasons:—First, it would have been hard to find a body of modellers who could have executed, in the given time, eight hundred feet of full size figures, in relief, with the same degree of excellence as could be secured by adopting the work of the painter instead of availing one's self of the sculptor's art. Secondly, if this difficulty could have been got over, the means at my disposal were quite insufficient to have met the expense of executing the work by the assistance of the latter. The total cost of the frieze, including the designs, their enlargement and fixing, was £4,426, and its area is 5,200 square feet. Has this decoration been too dearly bought? To say that another mode of decoration would be more



No. 1

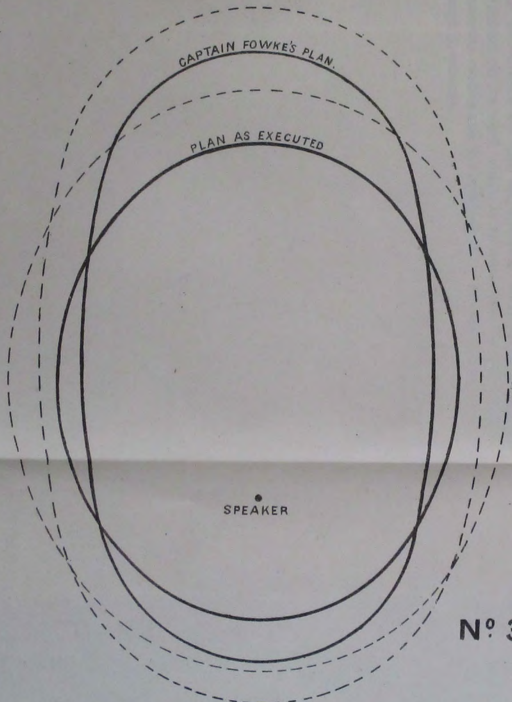


No. 2

SCALE OF 10 5 0 10 20 30 40 50 60 70 80 90 100 FEET.

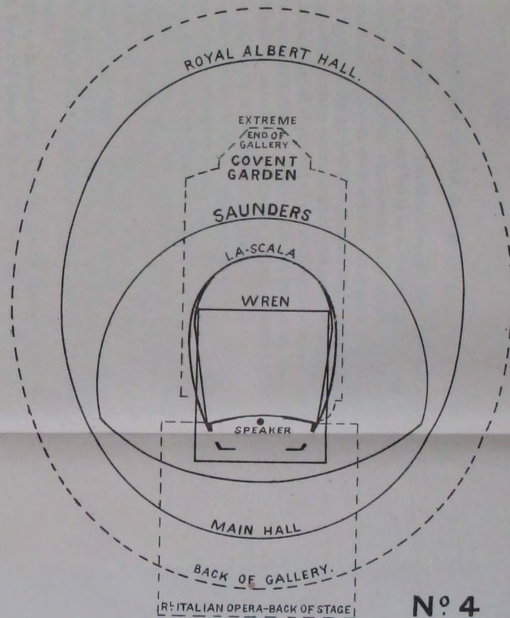
PL. XVI.

DIAGRAM TO SHOW THE SHAPE OF HALL DESIGNED BY CAPTAIN FOWKE AND OF THE HALL AS NOW EXECUTED BOTH PLANS DRAWN TO SCALE.



No. 3

DIAGRAM SHEWING RELATIVE SIZES OF R.A. HALL OF CHURCH GIVEN BY WREN, OF SAUNDERS'S PLAN AND TO THE THEATRES LA SCALA AND COVENT GARDEN.



No. 4

PL. XVII.

effective, if that mode be impossible under the conditions of the case, will not settle the question of the mosaic flat treatment being or not being one that ought to be repeated. In discussing the question, the facility with which the artist's work can be effectually rendered in mosaic work without much artistic feeling or knowledge of the human figure on the part of the operator, ought not to be lost sight of. For modelling in relief every workman employed must be an educated artist, unless the architect is satisfied that want of art shall be the characteristic of the work. I venture to suggest, also, in favour of a flat treatment, that, in London, soot deposits and birds' nests have somewhat marred the effect of the sculptured figures in the pediments of our public buildings.

The Messrs. Lucas Brothers were the chief contractors, and the well-known character of their foreman, their boldness in meeting the views of the architect, and their ability in coping with the most formidable difficulties did not forsake them here. For clerks of the works I had Mr. Hemsley, who showed the most zealous attention to his work, and Mr. Sankey, who superintended the preparation and fixing of the roof to my entire satisfaction. I was also much indebted for assistance to many other gentlemen, but I must not detain you by particularizing the nature of the assistance they rendered. I ought not, however, to pass over the name of Mr. Charles Stephenson, who afforded me great assistance throughout the whole work.

The chief points of interest in connection with the construction of the Albert Hall have now, I think, been mentioned to you. To have given a complete description of the building would, as I have already said, been impossible within the time prescribed for the reading of this paper. I trust, however, that the questions which I have touched upon with such imperfection, will raise discussions that will throw ample light upon them. It is unnecessary for me, I feel sure, to crave your forbearance for this imperfection, whatever may be the severity of your criticisms on the work which, in reliance upon the assistance to be derived from numerous models and the opinions of my friends and advisers, I have been bold enough to execute.

H. Y. D. S.

PAPER IX.

DESCRIPTION OF KING'S COUNTERPOISE GUN CARRIAGE AND PLATFORM,

AND

REMARKS ON THE USE OF DEPRESSING GUN CARRIAGES IN BARBETTE BATTERIES.

By LIEUTENANT BUCKNILL, R.E.

Iron structures and shields have, as yet, found no prominent place in the coast defences of the United States. The discovery of a trustworthy and efficient counterpoise gun carriage and platform, capable of mounting the heaviest ordnance economically and with good effect, is therefore a greater desideratum to the Americans than to ourselves, who employ iron so largely in all our coast defences. Since Capt. Moncrieff's carriage became known, several contrivances of a similar nature have been invented in the United States. Among them is one designed by Major W. R. King, U.S. Engineers, which has been deemed worthy of the most careful experimental trials, and has been demonstrated to be a complete success, and to compare favourably, both in economy and efficiency, with all other inventions of a like nature.

The writer was fortunate in seeing one of these carriages a few months ago, and the impression at once given was the exteme simplicity and probable economy of the entire arrangement. The following facts will prove its efficiency :—

The heaviest gun thus mounted is the 15 in. Rodman, weight about 50,000 lbs., charge 100 lbs. mammoth powder, solid shot 450 lbs.

The carriage has already withstood more than 100 rounds, as above, varying from 3 deg. of depression to 30 deg. of elevation.

The greatest number of gunners in a detachment to be of any use is ten, and the least number to work the gun with facility is six, although four *can* load and fire after the gun is run up for the first shot, and it is possible for a single man to run the gun up by himself. With gun detachments that have not been trained and drilled to the carriage, the minimum rate obtained has been about 2½ minutes. Calculations have been made which lead to the belief that King's carriage can be made for somewhere about one half the cost of Moncrieff's.

The apparatus is thoroughly explained in the following extracts from a paper on Counterpoise Gun Carriages, published in connection with the Professional Papers, Corps of Engineers, U.S. Army, in 1869, since which however some of the minor details have been improved upon:—

"Plate XVIII. represents a 15 in. gun carriage and platform at Fort Foote, Maryland, as modified to meet the requirements of the counterpoise system. . . . . . . Beginning with the platform, the first operation was to remove the pintle block and dig a well immediately under it, 15 ft. deep and 8 ft. in diameter. This well was walled up with arch-bricks, the wall being 18 ins. thick and resting on a foundation of concrete. In order to get into the well, a gallery was run under the parapet from the ditch; though, if several guns were to be mounted in this way, it would be best to run a gallery parallel to the interior crest of the parapet so as to communicate with all the wells from the interior of the work. The pintle block was then replaced and bolted down by four vertical iron rods passing through cast iron sockets, built into the wall about 4 ft. from the bottom of the well. These rods are intended to answer the double purpose of holding the pintle block in position and of acting as guides to the counterpoise. . . . . The pintle is 8 ins. in diameter, and has a 4 in. hole for the ropes. This dimension is assumed on the supposition that two ropes, $1\frac{3}{4}$ ins. in diameter each, are ample to sustain the counterpoise and should it be found necessary or desirable to use more ropes or larger ones, a larger pintle could easily be substituted.* . . . . The slope of the chassis is fixed at $18\frac{1}{2}$ degrees, and this appears to be, all things considered, about right. . . . . For the purpose of throwing the top carriage into and out of gear, in order to let it run into or out of battery, the rear wheels only are provided with an eccentric axle. The front wheels always bear upon the chassis, and the front end of the top carriage is cut away on the bottom as far back as a vertical line through the axis of the trunnions, so that when the rear end of the carriage is raised by the eccentric, the front end is also clear of the chassis and rests upon the wheels; but when the rear is thrown out of gear the whole weight of the gun slides upon the chassis. In running the piece up into battery, it is therefore necessary only to raise the rear end of the top carriage, which can be done by two men, since only about one-fifth of the weight of the gun bears upon the rear eccentric, and the counterpoise will start the gun. . . . . To provide against the contingency of the gun being stopped before it reaches its proper position for firing, as well as to run it back for loading the first time, cranks and chains are attached to the sides of the chassis. . . . . . In ordinary practice it is not supposed that these will be needed, and the pawls which connect the top carriage with the chains are to be habitually detached from them and held up by the spring, instead of the position in which the drawing shows them. When wanted for use they are pressed down, and as the cranks are turned, bringing the chain along, they drop into the links and thus attach the top

* This change has been effected, four ropes in place of two being now employed.

carriage to the chains; but, as soon as the chain stops moving, the spring at once detaches them from the chain and holds them up out of the way, as before mentioned. The cranks and chains are entirely independent of each other, and either can be used alone in case the other becomes unserviceable. . . . . . A friction brake is placed near the fulcrum to prevent the breach of the gun from being thrown down too far when the muzzle draws over the roller at the front of the carriage. It will be seen from the drawing that the ends of the ropes are fastened to a hinged socket, or swivel, at the middle of the front transom of the top carriage, the ends being bent outwards about 90 deg. each, so as to bring the fastenings some distance apart while the ropes draw close together, and in that manner run over the pulley and through the pintle into the well. . . . . The weight of the counterpoise is, in round numbers, 45,000 pounds, one half of which comes upon the carriage and the other upon the fastening at the pintle block—that of the chassis or slide 16,000 lbs., and that of the carriage 9,000 lbs. The strain upon the rope when the gun is fired is made up of two parts, one due to the *weight*, and the other to the *inertia* of the counterpoise. The former is 10,500 lbs., or one-fourth of the whole weight of the counterpoise upon each section of the rope. The latter depends upon the rate at which the gun acquires its velocity, and upon the elasticity of the system. With a charge of 50 lbs. the 15 in. gun attains its maximum velocity in less than one inch from the starting point, and its connection with the weight is such that, leaving elasticity out of the account, the latter must acquire about one-half of its velocity in one-fourth of this space. It is, therefore, evident that some elasticity must be provided for, in order to secure additional time for the weight to move, and thus diminish the strain upon the rope. This was sought to be accomplished by the use of a steel-wire rope, and by placing rubber springs below and between the sections of which the counterpoise is composed. In order to test the efficiency of this arrangement, a cylinder was placed and caused to revolve uniformly in a vertical position near the counterpoise, to which was attached a pencil. On the gun being fired, the pencil described a helix, which, when developed, was found to coincide almost exactly with a parabola for some distance from the initial point; and it was also found that the weight had been raised about two inches for the 50 lbs. charge, before it attained its maximum velocity. The parabolic form of the curve showed that the force producing the velocity—the strain upon the rope—was sensibly constant, and the distance passed over in acquiring the velocity was as great as that which the force of gravity would require to generate the same velocity, which amounts to saying that an additional strain upon the rope, equal to the weight of the counterpoise, would have produced this motion. We have, therefore, a total strain upon the rope, for a 50 lbs. charge, of 10,500 $\times$ 2, or 21,000 pounds. The work of inertia developed in the gun and counterpoise should increase a little faster than the weight of the charge, other circumstances being equal, and we should therefore have for the additional strain due to a charge of 100 lbs., say 25,000 lbs., making the total strain upon each rope for this charge 35,500 lbs. . . . . It should be stated that one object of the moveable pulley, attached to the counterpoise, is to diminish the velocity of the counterpoise and thereby reduce the work of its inertia. The velocity is divided by 2 and the weight multiplied by 2; but since the square of the velocity enters the expression for the work of inertia, with the first power of the weight, it is clear that the effect of the arrangement is to divide the whole work of inertia, and hence the strain upon the rope, by 2,

$$for\ 2W\left(\frac{V}{2}\right)^2 = \frac{WV^2}{2}$$

With regard to the probable durability of the rope, it may be remarked that, under favourable circumstances, similar ropes have been in almost constant use for many years, for hoisting gear and other purposes; and as this rope will have to run to and fro only about 1,000 times in order to outwear an ordinary service cannon, it is evident that with proper attention to its preservation, no doubt need be entertained with regard to its durability." . . . .

In another portion of the same volume a point is noticed respecting Major King's carriage, worth recording. "The rope from the top carriage to the pulley runs nearly at right angles to the direction of motion as the gun starts to run back, so that the shock of the recoil is transmitted gradually to the counterpoise; but as the gun runs further back, the rope becomes more nearly parallel to the chassis, and the component of the rope's tension which directly opposes motion increases until the gun is brought to rest; while the normal component which increases friction, beginning at nearly the whole weight of the counterpoise, gradually diminishes and finally becomes very small when the gun has reached its lowest position. The first of these components varies with the cosine, and the latter with the sine of the angle which the rope makes with the chassis. When the eccentric wheels are thrown in gear, the weight of the counterpoise starts the gun into battery, the acceleration gradually diminishing until finally, at some point above the middle of the chassis, the horizontal component of the weight of the gun becomes equal to that of the counterpoise; but the momentum acquired by the gun carries it on, even after the horizontal component of the counterpoise has become less than that of the weight of the gun, and the gun arrives in battery with nearly the same velocity which it has when allowed to descend upon a chassis of the ordinary declivity towards the front, the motion being regulated and checked at the proper time by throwing the eccentric wheels out of gear. The counterpoise is, therefore, started and stopped gradually, and without any considerable jerk, both in running into and out of battery. It also acts to prevent the front end of the top carriage from jumping up when the gun is fired, and it gives stability to the chassis, and diminishes the shock upon the pintle." . . . .

An objection has been urged against this description of counterpoise carriage, to the effect that it would be inapplicable to guns over casemates, on account of the necessary well. This is not so, for there is no absolute necessity for placing the well immediately under the carriage, and the rope may be led by a suitable arrangement of pulleys to any convenient position, either in front or rear, where room may be found for the motion of the counterpoise. Loss of power would occur through additional friction and stiffness of cordage, but more elasticity would be obtained by the greater length of rope.

Remarks on the Use of Depressing Gun Carriages in Barbette Batteries.

The highest authorities in the United States, on questions appertaining to Fortifications and Coast Defences, in the year 1869, recommended—

"First. The construction, wherever the site will permit, of cheaply built barbette batteries with magazine traverses between each pair of guns; a parados, where necessary, to guard against reverse fire; and *generally* wooden gun-platforms. Such batteries may hereafter be readily modified for the use of depressing or counterpoise carriages, and, unless on very elevated sites, should be planned having this in view."

"Second. The substitution for the barbette carriage of one which will admit of the depression of the gun below the crest of the parapet, for loading."

And further, alluding to the Moncrieff carriage and other forms under which the depressing carriage was then being studied in connection with these barbette batteries, they remarked, "in the achieving of a practical result, may be found a way of attaining an efficient service of modern sea-coast artillery when the proper sites present themselves."

Again, in 1871, the same authorities set forth "the necessity for a depressing gun carriage for barbette batteries having a low or even a medium reference above the water level; its utility for those even which are usually called high batteries; and the advantages derived from a high covering parapet for all open batteries."

From the year 1869, therefore, the introduction of a depressing gun carriage into all sea-coast batteries, except those on very elevated sites, has been regarded in America as a necessity, "for, if the iron-clad be not a failure it can pass near enough to throw shells with some degree of accuracy at shore guns, and can at least use grape and canister with efficiency against them. It is not believed that the gunners will stand to their pieces, and sponge and load them, under such fire, in low batteries, and probably not in those of medium height." Hence trials have been made of those depressing carriages that gave reasonable promise of success. "If we must have barbette batteries, we must have cover for the gunners while loading, and a high covering parapet to protect them as far as possible in all parts of the terreplein. And the only question that seems at all open for discussion in this reference is how far a high battery may shield them from the severe fire which would make the low one unserviceable. Now, in the high battery, the men while loading are but partially exposed to the fire coming from ships that have approached as close as they dare to the shore, and in all parts of the terreplein they are quite well covered. As the hostile fire becomes more distant, the protection due to height becomes less and less, but the accuracy of that fire diminishes rapidly with the increased distance."

"To set forth fully this question of cover attained by high reference of parapet —by high parapet—and by the use of a depressing carriage, the Board has caused drawings to be prepared, showing the trajectories of 12-in. rifled shot fired at angles of elevation from 1 deg. to 8 deg. inclusive, with charges of

70 lbs. and with initial velocities of 1183 ft. In connection with these trajectories, sections of the parapets of batteries have been constructed with different elevations, so, that these trajectories shall touch the interior crests of the sections at distances from the initial point varying from a quarter of a mile to a mile and three quarters. The object of this drawing is to show the direction of a solid shot as it passes over the terreplein of batteries at different heights above the water, and fired from ships at different distances. In fact to exhibit the varying conditions of an attacking fleet in relation to shore batteries of various heights."

"It is believed, that vessels must be near enough to use grape and canister, or near enough to attain accuracy of fire with shot and shell, to silence a shore batttery. Distant fire alone from ships cannot stop the fire of batteries, though it will give essential aid to close fire, especially if delivered very obliquely to the parapets. It is probable that canister will not be efficient beyond a quarter of a mile, and that grape will not be used beyond half a mile. Solid shot beyond half a mile, to be efficient, must be poured in rapidly. Shells, however, will doubtless be used more abundantly than solid shot at all distances. It is in fact the fire from a quarter of a mile distance up to three-quarters of a mile, or at most a mile, that fleets must rely upon to overwhelm sea-coast batteries."

"Comparing the different sections on the accompanying drawing, some estimate may be formed of the partial security gained for the gunners by elevating the battery. At the distance of a quarter of a mile, and with a reference above the water level of 160 ft., the terreplein is well covered, and the gunners in loading are not much exposed; not more so than through an embrasure or a port-hole. Of course, the cover is by no means perfect, and the exposure will somewhat interfere with the rapid and accurate service of the piece; still it is believed that gun for gun, the battery would maintain itself against an iron-clad."

"At the distance of half a mile, the protection due to the same height of reference is less than at a quarter of a mile. The terreplein is well covered as against direct shot, in this, as in the former distance. It is probable, that less accuracy of fire from the ship by reason of increase of distance, will quite offset the greater exposure of the men in loading, and, that grape would not silence this battery 160 ft. high, provided the opposing armaments were equal gun for gun. But at both of these, and at all intermediate distances, the fire either of canister or grape (though the greater part of the charges must of necessity be wasted) would attain the interior by so curved a flight, that even in this high battery, a greater cover than 7 ft., as hitherto practised, is desirable."

"At three-quarters of a mile distance, shells would take the place of grape. While the cover due to height, both in loading and on the terreplein, is rather better in the high, than in the low battery, the difference is by no means so great as at the closer ranges. But it is more difficult to hit a mark on a height, than on the same level, and it is not at all probable that the exposure to solid shot or shell is sufficient to prevent the service of the pieces, unless there be a disparity of guns in favour of the attack. But at all these distances, there would be a better feeling of security, were the breast height 11 ft., instead of 7 ft. As the distance of the ship increases, the difference of protection or cover, given by a high or low battery, becomes smaller and smaller, and if the distant fire be oblique, as shown on the drawing, the height of 7 ft., hitherto practised for interior slopes, is entirely inefficient. The drawing illustrates this, by showing the relative positions of the descending curve of fire into the battery, and the two terreplein levels, one 7 ft. and the other 11 ft, below the crest. It is true, that from the distant ships the greater portion of the fire must be lost, and that only an occasional shell would graze the parapet, or burst just at the right point to throw in destructive fragments. But the higher the covering parapet, the better are the chances for the gunners on the terreplein to escape these fragments. Now as batteries are, or may be, liable at the same time, to all these attacks, by the different ships of a fleet taking distances from a mile and a half down to a quarter of a mile from the shore guns, it seems necessary, in order to procure efficiency of service in the land battery, even if high, to give the cannoniers all the cover that can be conveniently attained by a high parapet. There can be no doubt that the depressing carriage will be served with more confidence by gunners in all positions high or low. Still, as its introduction involves more space, not always available, and an additional cost of perhaps 7000 dollars per gun, there will be positions (as for instance where there is a large array of shore guns on each side of the channel of approach to a harbour, or where hostile ships will have difficulty in developing themselves favourably for an attack), that will admit, in some of the higher barbette batteries of a good service of guns mounted on non-depressing carriages. In these batteries, however, as much covering height for the parapet should be attained as possible."

The conclusions arrived at were summed up as follows :—"The necessity for the depressing carriage admits of no doubt, and as before observed, its introduction is but a part of our system of defence by earth batteries; and for high batteries, where it may be possible to dispense with its use, some further study should be made as to the application of the non-depressing carriage to a higher covering parapet. A tracing to accompany the foregoing is herewith transmitted."

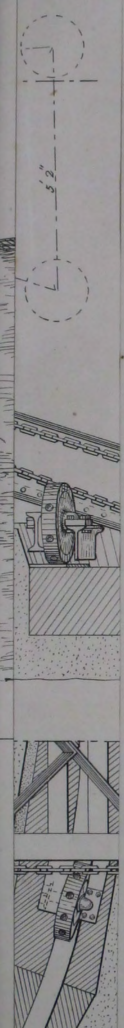
The foregoing extracts are taken from a report on the subject, printed in the United States last year.

J. T. B.

MAJOR

TO A

AT



PAPER X.

METHOD OF DETERMINING THE DYNAMIC EFFECTS OF VARIOUS EXPLOSIVES WHEN DETONATED UNDER WATER.

BY LIEUTENANT BUCKNILL, R.E.

General Abbott, United States Engineers, has for some time past been carrying on a series of experiments with various explosives, with a view to determine the different dynamic effects produced by their detonation under water, and to apply the knowledge gained therefrom to the sciences of torpeding and submarine mining. In February last, upwards of one thousand experiments had taken place, and, as the manner of procedure has produced results, in the exactitude of which the officers engaged seem very confident, a a short description of the same may not be out of place in the Corps Papers.

A strong buoy of boiler-plate iron, some 5 ft. 6 in. long and 2 ft. in diameter, with a conical bottom, supports, by means of chains or wire ropes, at any required depth below it, an iron ring, Pl. XIX., Figs. 1 and 2, in a horizontal position. This ring is made of flat iron, with the edges pointing towards the centre, the section of the iron varying with the charge to be exploded, and with the diameter of the ring. The exact dimensions for various conditions were not discovered; but from other parts of the apparatus that fitted on the rings, I should judge that they are formed of iron about $\frac{3}{8}$ of an inch thick, and from 5 to 12 in. in breadth. Six pressure plugs are attached to this ring, at equal distances apart, by means of strong iron cups, from the back of which two long ears project. These ears engage with the ring, and are fixed thereto by means of a wedge and cotter, as shewn in Figs. 3 and 4. On the interior of the cup, a fine thread is cut, in which the case containing the pressure plug is screwed. This case is a cylindrical box of iron (Fig. 5), threaded half way up the exterior, to engage with the interior of the cup. On the interior, the case is turned out to a diameter of $1\frac{3}{4}$ in., and some small horizontal grooves cut on the surface of the bottom portion, and on the upper half a screw thread is cut. A small metal point is left in the centre of the flat surface at the bottom, on which the pressure plugs—which are previously indented for the purpose—are centred.

The size of the plugs varies with the experiment. Some are but $\frac{1}{2}$ an inch in diameter, and $\frac{5}{8}$ of an inch long; others are $\frac{5}{8}$ of an inch in diameter and 1 in. long; others still larger. Great care is taken to ensure the homogeneity of the plugs. The piston *c*, Fig. 7, covers the plug as in Fig. 9. Several vertical slots are cut on the exterior surface of the piston, so that the pressures on either side may equilibrate both before and immediately after an explosion. The piston also carries two or more spring catches, which engage with the grooves on the interior surface of the lower part of the box or case *a*, and keep the piston at the point to which it is driven by the explosion.

The cylinder cover *b*, Fig. 6, is next screwed into *a*, a copper washer having previously been inserted between them. In the centre of this cover, a hole 1 in. in diameter is bored, in which the smaller portion of the piston *c* exactly fits. A gas check *d* (Fig. 8), of thin brass, is then placed on the top of *c*, and the pressure plug is ready for lowering.

The charge *p* (Figs. 1 and 2) is hung from the buoy, and secured with wire or other means, exactly in the centre of the ring. After explosion the ring is raised, and the mean compression of the six plugs taken. This is compared with the compression produced by the fall of a weight through a certain height on a similar plug.

It was intended to proceed with experiments of a like nature in deeper water, with the apparatus modified as follows:—

In place of a horizontal ring and buoy, it was proposed to lower the charge to be experimented on in a large frame, some 50 ft. long and 12 or 14 ft. square. This frame was finished, but had not been used in February last. It was built up of iron about $\frac{1}{2}$ in. thick and 7 to 10 in. in breadth, and each piece was so placed that the edges of the iron were presented to the centre or position of the charge. Pressure plugs were to be placed as before, at various positions, facing the centre, and the huge frame then lowered from a floating stage, by a derrick, to any required depth.

J. T. B.

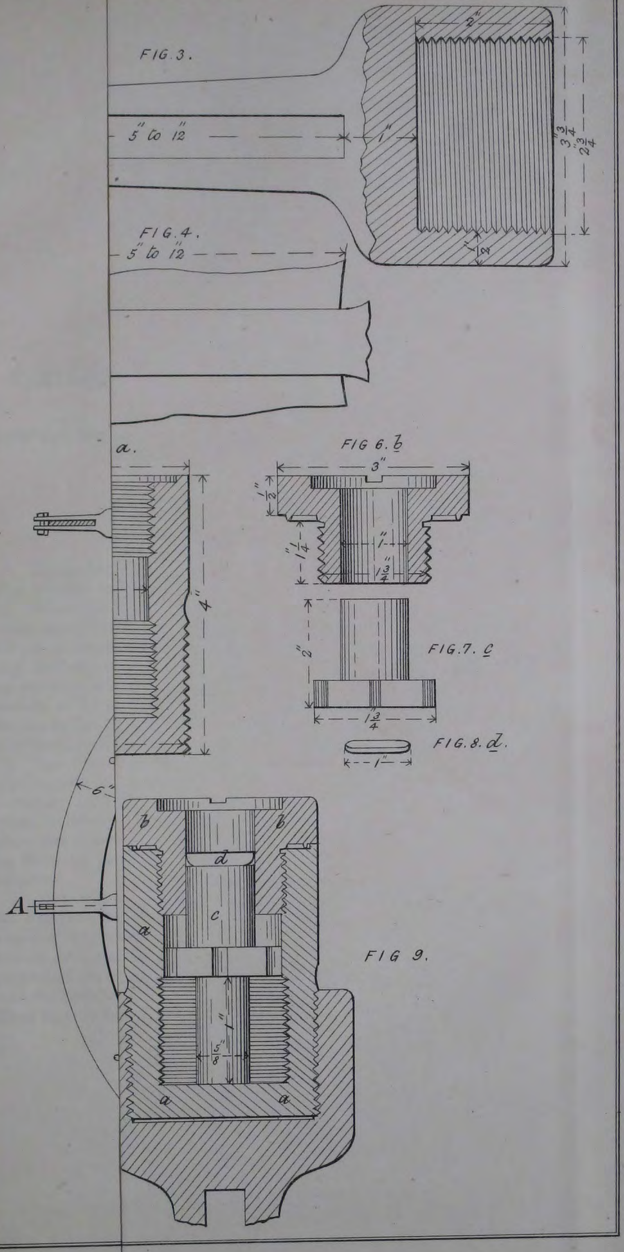


FIG. 3.
5" to 12"
1"
2"
3 3/4"
2 3/4"
1/2"
FIG. 4.
5" to 12"
a.
4"
6"
A
FIG 6. b
3"
1/2"
1 1/4"
1"
1 3/4"
FIG. 7. c
2"
1 3/4
FIG. 8. d.
1"
FIG 9.
b
d
c
a
1"
5/8"

PAPER XI.

THE ART OF AËRONAUTICS APPLIED TO WAR.

Translated from the "Jahrbücher für die Deutsche Armee und Marine." October, 1872.

BY CAPTAIN G. E. GROVER, R.E.

1. It may fairly be expected that the war of 1870-71 will prove the starting point of a new era in the art of Aëronautics.

2. When the French capital was completely surrounded by the German armies, in September, 1870, it became necessary for the Government of National Defence to devise a means of conveying intelligence, in order to bring about, by some method, communication with the outer world. After various ineffectual attempts at communicating by means of messengers disguised as vegetable huxters, or by specially trained dogs, or by hollow bullets concealed inside the bearer, &c., &c., they proceeded, as was natural, to use balloons, in order to gain the desired end.

3. The French Government went to work with all energy. They caused large balloons to be made, of which fifty-four left the city between the 23rd September, 1870, and the 28th January, 1871, bearing altogether 2,500,000 letters, weighing 10,000 kilogrammes (197 cwt.), and carrying two or three passengers apiece. With the exception of a few which fell into the hands of the Germans, or perished in the sea, all succeeded in duly delivering their contents.

4. However, this application of air balloons, to relieve the great distress of the Parisians, was but one-sided. As navigable air balloons were not yet invented, they could only employ those built on the old system, which were necessarily at the mercy of the prevailing winds, and were thus useless for the purpose of conveying news into the besieged city. Some balloon passengers, with the last-named object, took carrier-pigeons with them, when starting, but found them to be very unreliable messengers, as only a small number got back.

5. The results obtained form a strong incentive to further progress in the art of Aëronautics, and to solve the old problem of this science, viz., the construction of navigable balloons. For every one must acknowledge that such balloons would be absolutely invaluable for military purposes.

6. The so called "captive balloons," from which an enemy could be reconnoitred, have already in several wars played a respectable rôle. For instance, in the battles of Fleurus and Solferino the balloon reconnoissances materially assisted to secure victory to the French colours.

7. Air balloons were also found useful, for purposes of reconnoitring, during the late civil war in America.

8. Thus Germany, France, and England, are now equally interested in newly testing the application of balloons to military purposes.

9. Assuming, then, that balloons could be utilized for duties of less importance than those of reconnoissance, navigable balloons would be of great use for the delivery of hurried orders between operating armies separated from one another, or for maintaining a communication with an invested fortress, or for sending to head-quarters important intelligence from the field. But, in consequence of the increased range of our modern artillery, balloons must necessarily be kept at a considerable altitude above the earth; and, on this account, the bird's-eye view would furnish an uncertain, insufficient, and inaccurate, survey of the ground to be reconnoitred.

10. It must furthermore be remembered that the employment of telegraphy in an enemy's country cannot always be depended on, in consequence of the numerous accidents to which the wires are liable. In many cases, indeed, a balloon would travel faster than a telegram by electricity; for, in the late war, there were several instances of messages from the scene of operations being delayed—in consequence of prior occupation of the lines, or of destruction of the wires—for three days and even more; whilst a balloon could have travelled the distance in a few hours.

11. The experiments in Aëronautics carried out by the above-named countries (Germany, France, and England), have born fruit in a number of new discoveries, of which two are specially important, viz.: those of M. Dupuy de Lôme, Chief Constructor in the French Navy, and M. Hänlein, an engineer, of Mainz. The first of these was fully described in the Paris journal, *l'Aéronaute*, which journal, be it remarked, *en passant*, bears the following notice as an outer expression of its Germano-phobia:—"*l'Administration n'accepte pas d'abonnements pour l'Allemagne.*" However, the following remarks may be made upon this invention.

12. From the results of past experience it had been fully established that a balloon, furnished with a screw, could move itself independently in the air; but no definite conclusions had yet been come to with reference to the proper form of the balloon, or the dimensions and special arrangement of the screw, or how the latter should be set in motion. This problem as to the proper mode of balloon construction, including all the attendant difficulties and uncertainties about an unknown region, has been fully solved by Dupuy de Lôme, who has

skilfully worked out the proper conditions for the security and strength of the apparatus, and has ingeniously calculated the relation between the dimensions of the screw, the resistance of the wind, and the balloon's ascensional force; so that, according to the experiments made, his theories were not only satisfactorily confirmed, but even exceeded.

13. In order to cause the smallest possible resistance to the wind, Dupuy de Lôme gives to his balloon a slender oval form, and in order to prevent the bag from becoming flabby, and thus hindering its navigability, he uses a small balloon inside and at the bottom of the big one, into which small balloon atmospheric air may be propelled by a fan through a valve and pipe leading from the car. By this method, when the bag or envelope becomes flabby in consequence of the escape of gas, the small balloon, inflated by air, fills up the vacuum, and the large balloon again expands. Thus, the contents of the small balloon restore the form of the large balloon, which thereby contrives to remain uniformly expanded, even when subjected to the atmospheric effects due to a height of 866 mètres (947 yards).

14. The length of the balloon is 36·12 mètres (118·6 ft). Its diameter in the middle, is 14·84 mètres (48·6 ft.); and capacity, 3454 mètres cube (121985 cubic ft.) The car is 6 mètres* (19·6 ft.) long, and its breadth is 3 mètres (9·8 ft.) The screw projects from one end of the car, and has two vanes, whose diameter is 9 mètres (29·5 ft.) They make on an average 21 revolutions per minute, and are worked by four men who are relieved half-hourly. By this means the balloon can advance 2·22 mètres per second, or 8 kilomètres (very nearly 5 miles) per hour. The steering rudder consists of a triangular sail, which is fastened beneath the balloon to a boom 6 mètres (19·6 ft.) long. The sail is 15 mètres (49·2 ft.) long, and its area is 15 quadrumètres (162 square ft.) To steer this sail-rudder, two ropes are carried from the rigging at the end of the car to the helmsman, who has a compass fixed before him in the car, and can by its needle steer in the direction required for the major axis of the car.

15. The arrangement of the netting is a peculiarly important discovery. That of the balloons used in the early experiments was attached to a large horizontal sail-yard from which hung the car, but this arrangement was somewhat dangerous, since in a downward journey the sail-yard might hurt the passengers, and besides it gave no useful strength or security to the balloon and car. Dupuy de Lôme, however, introduced a double net, viz., an outer and an inner, of which the former bears the car, whilst the latter covers only three-fourths of the balloon, and forms a cone beneath it, with the apex coming half-way between the balloon and its car. From this apex proceeds a system of rigging which keeps the car in equilibrium; so that, even if eight men therein are hard at work, the position of the balloon is not altered half a degree from that which it had when at rest; and if a man proceeds from one end of the car to the other, the position of the balloon is not altered more than two-thirds of a degree.

* There is apparently some mistake in this dimension. The other account (see page 79) gives the car's length at 41 ft. 3 in.—Tr.

16. The ascent * made on the 2nd of last February, 1872, ought to determine whether or no the balloons constructed on the plans of Dupuy de Lôme are worthy of approval. The balloon ascended, as is well known, from the parade of Fort Neuf, in Vincennes, during a brisk wind, and it well maintained its position in the air, the influence of the steering rudder making itself perceptibly felt, and the rapidity of progress exceeding that of any balloon previously designed. With the same balloon, the rate of 10¼ kilomètres (nearly 6 miles) per hour, which was attained on the 2nd of February, could be increased to 22 kilomètres (14¾ miles) per hour, if, instead of the eight men, a steam engine were placed in the car so securely that the danger of an explosion need not be feared. With the construction of such a machine Dupuy de Lôme is now fully occupied.

17. Towards the end of last year (1871), Mr. Hänlein, of Mainz, an engineer, carried out, at Vienna, some experiments with a small balloon prepared by him, and obtained results which were so far satisfactory, that the Chamber of Commerce (*Gewerbeverein*), of Lower Austria, voted from 30,000 to 40,000 guldens, (from £2,916 to £3,888) to be spent in constructing a large balloon, to be completed, at the latest, by the opening of the Great Exhibition at Vienna, in 1873, so as to demonstrate the Hänlein system. †

18. The steering apparatus of Mr. Hänlein's balloon consists of an air screw, made to revolve by means of the Lenoir gas engine, whose requisite driving gas is derived from the balloon, and ignited by a small Ruhmkorff coil. There is no danger of fire, as the light cannot spread. Besides this, the ballast indispensable for every balloon is, in Hänlein's project, precisely the means necessary for replenishing the gas engine's driving power, viz., sulphuric acid and water, which waste away in proportion to the length of time the gas engine works, and to the diminution in ascending power sustained by the balloon through the loss of gas taken from it by the gas engine.

19. The Hänlein system, consequently, possesses the advantage that it does not burden the balloon with a heavy mass of machinery, and there is no need of special materials from which to obtain driving power for the steering. The weight borne by the balloon consists only of the screw and gas machine, so that a great difficulty, which has hitherto prevented the navigation of a balloon, is thereby overcome.

20. From a patriotic point of view, all must earnestly hope that the forthcoming experiments with the Hänlein system, on a large scale, will confirm those previously undertaken, so that Germany may benefit by the employment of balloons in warfare.

* This experiment was made in the presence of an official commission, nominated by the Minister of Public Instruction. The balloon ascended at 1.30 p.m., carrying 14 passengers, viz., MM. Dupuy de Lôme, Lédé, Engineer in the Marine, Yon and Dartois, aëronauts, and 10 other persons.—Tr.

† I am informed, however, that it is highly unlikely that this Hänlein balloon will be shown at the Vienna Exhibition.—Tr.

NOTES BY TRANSLATOR.

The article in the "Jahrbücher für die Deutsche Armee und Marine,"—of which the foregoing is a translation—is said to have been written by a Prussian Captain of Engineers, who has made a special study of military aëronautics. The subject is certainly of great importance from a military point of view, and its value has always been fully recognised in this country. It is hoped that the following remarks may assist in establishing the value of the article, but they will not undertake a critical investigation of the two schemes set forth therein. It is as yet early to decide positively against them, and the forthcoming experiments will be watched with much interest; but, it certainly does seem that hitherto no motive force has been discovered of sufficient power, and produced by sufficiently light agents, to affect materially the wind-caused direction of a balloon.

Paragraph 6.—"In the battles of Fleurus and Solferino, the balloon re- "connoissances materially assisted to secure victory to the French colours." The French balloon reconnoissances made at Fleurus, in 1794, and at Solferino, in 1859, were described by the writer ten years ago in the "Royal Engineers Professional Papers," Vol. XII., pages 77, 78, 87, 89. The latter appears to have been by no means successful, and the former, though usually described by historians as a valuable means of reconnoissance on the occasion, was not so considered by Jomini, who describes the event as follows, in *l'Art de la Guerre*, chap. vi., art. 42, (Mendell's translation):—An attempt of another kind was made in 1794, at the battle of Fleurus, where General Jourdan made use of the services of a balloonist to observe and give notice of the movements of the Austrians. I am not aware that he found the method a very useful one, as it was not again used; but it was claimed at the time that it assisted in gaining him the victory: of this, however, I have great doubts. It is probable that the difficulty of having a balloonist in readiness to make an ascent at the proper moment, and of his making careful observations upon what is going on below, whilst floating at the mercy of the winds above, has led to the abandonment of this method of gaining information. By giving the balloon no great elevation, sending up with it an officer capable of forming correct opinions as to the enemy's movements, and perfecting a system of signals to be used in connection with the balloon, considerable advantages might be expected from its use. Sometimes the smoke of the battle, and the difficulty of distinguishing the columns, that look like Lilliputians, so as to know to which party they belong, will make the reports of the balloonists very unreliable. For example, a balloonist would have been greatly embarrassed in deciding, at the battle of Waterloo, whether it was Grouchy or Blucher who was seen coming up by the St. Lambert Road; but this uncertainty need not exist where the armies are not so much mixed. I had ocular proof of the advantage to be derived from such observations when I was stationed in the spire of Gautsch, at the battle of Leipsic; and Prince Schwarzenberg's aide-de-camp, whom I had conducted to the same point, could not deny that it was at my solicitation that the prince was prevailed upon to emerge from the marsh between the Pleisse and the Elster. An observer is doubtless more at his ease in a clock tower than in a frail basket floating in mid air; but steeples are not always at hand in the vicinity of battle-fields, and they cannot be transported at pleasure." Such are the Baron de Jomini's views upon balloon reconnoissance.

A somewhat recent instance of the use of reconnoitring balloons in war occurred in 1867, when the Brazilian army operating against the Paraguayans, under President Lopez, employed a captive reconnoitring balloon, under the management of Mr. Allen, an aëronaut from the United States. The Parliamentary Blue Book, "Correspondence respecting Hostilities on the River Plate, 1868," contains what purports to be "a plan of the seat of war in Paraguay, taken from the balloon," and the following remarks as to its employment, by General Mitre, the Commander-in-Chief:—"President Mitre to Vice-President Paz. Head-quarters, Tucucuè, December 4th, 1867. With regard to the balloon, I will inform you that it can be employed to carry out any observations that may be required, and that with the assistance of a glass your view embraces a considerable extent of ground in all its details; but it is absolutely necessary that the observer should have acquired sufficient practice to enable him to balance his body so as to counteract the oscillation of the balloon, otherwise the use of the glass is impossible, and the observations, therefore, of but little importance. This is the reason why most of those who have been up in the balloon have only been able to see with the naked eye. The Engineer in the Argentine service, who is well acquainted with this fact, owing to his former experience in the United States, has made from it several very important observations. He has been able to see the enemy's line of earthworks in all their details on two sides of the quadrilateral, and discover which of the passes through the Estero Ballaco were fortified. He has also seen from hence Corrientes, Ytati, and Villa del Pillar. The balloon has never been employed in any battle, and it has very seldom been used. My opinion on this subject is that the balloon may be often employed with advantage in war, and that if the one we have has not been of much service, it is owing to our not having known how to make proper use of it."

The employment of a reconnoitring balloon by the Prussians at the siege of Strasburg is generally understood to have been a failure. The special correspondent of the *Daily Telegraph* wrote from Schiltigheim on the 25th Sept., 1870:—"The much talked of balloon made two small attempts at ascent yesterday, but burst at the second, and will not be fit for another experiment before Monday, when (weather permitting) it will go up at four p.m." On the 27th Sept., however, Strasburg capitulated.

Sir Garnet Wolseley points out in "The Soldiers' Pocket Book," page 201, that "Balloon ascents by night, particularly in wooded countries, are most useful for the purpose of reconnoissance, as the fires indicate the enemy's position, and his numbers may be roughly estimated by allowing 10 men to each fire. During an action, a staff officer in a balloon at the elevation of 1,000 or 1,200 ft. would be of infinite service. The ascent should be made from some height, about a mile in rear of the skirmishers; a telegraphic wire from the car should lead to the spot where the General in command had established himself, who could then be kept acquainted with where the enemy's reserves were posted, &c.

Paragraph 4.—"For the purpose of conveying news into the besieged city, some balloon passengers took with them carrier pigeons." The following paragraph on this subject appeared in the *Army and Navy Gazette*, of the 7th Dec., 1872 :—"The partial success which attended the employment of carrier pigeons by the French in the late war, has induced the Germans also to experiment for themselves on their usefulness in modern warfare. Stations for training these messengers have consequently been established this summer at Cologne, Metz, Strasburg, and Berlin. If their employment should prove satisfactory, they will be introduced into all German fortresses. At the outbreak of a war, the trained pigeons of the different stations will be sent to a central stat on, and *vice versâ;* and these places will thus possess, as long as the supply lasts, a safe means of communication, while the war is not yet carried up into the air. It is not yet settled to which branch of the service they will be attached, but they will most likely be confided to the care of the Engineers."

Paragraphs 12 *to* 16. The Dupuy de Lôme balloon. A good account of this balloon, and of the ascent it made on the 2nd February, 1872, is given in *Engineering*, of the 16th February, 1872. It is important to study all the particulars of so novel an experiment on a large scale, and, therefore, the entire passage will be transcribed :—

"The construction of this aërial machine starts with the principle, that to obtain a navigable balloon, the two following conditions must be complied with :

1st.—"The permanence of the form of the balloon, without any sensible undulation of its surface.

2nd.—"Obtaining a horizontal axis of least resistance in a direction parallel to the propelling force.

"The permanence of form is assured by a fan carried in the car, and put in communication by a tube with a small balloon placed within the large one at its lowest part. The volume of this small balloon is one-tenth of that of the large one. It is furnished with a valve opening both within and without, and regulated by springs. The large balloon is provided with two hanging tubes open to the air, and falling for a distance of 25 feet from the lower part of the balloon. The inflation of the little balloon causes the hydrogen to fall more or less in the hanging tubes, but never sufficiently to force it out of their open ends.

"To obtain a horizontal plane of least resistance, the form given to the balloon was that developed by the arc of a circle turning around its chord, and in which the versed-sine was nearly one-fifth of the length of the chord.

"The following are the principal dimensions of the balloon :—

	Ft.	in.
Total length, from out to out	118	6
Greatest diameter	48	9
Cubic contents	122,000	0
Total height from the top of the balloon to the bottom of the car	95	6
Length of the car	41	3
Greatest width of the car	10	8
Diameter of screw	29	6
Pitch of screw	26	2

Ascensional Force.	Tons.
With small balloon not inflated	3·799
Ditto ditto inflated	3 419

Number of revolutions of screw per minute, to obtain a speed of 5 miles per hour	21
Time required to fill the small balloon by aid of the fan	15 minutes.

"The upper portion of the balloon is covered with an envelope of fabric, which supports the car by a zone placed around the centre of the body. This envelope is then continued below the upper half until it covers about three-fourths of the body. Below the envelope, and attached in a similar manner, is a second zone within the first one, having the form of a cone tangential to the sides of the balloon. The summit of this cone serves to attach the cordage by which the car is sustained.

"The rudder consists of a triangular sail placed beneath the balloon and near the rear, and it is kept in position at the bottom by a horizontal yard, 19 ft. 8 in. long, turning around a pivot on its forward extremity. The height of this sail is 16 ft. 4 in., and its surface 161 square feet. Two ropes for working the rudder extend forward to the seat of the steerer, who has before him a compass fixed to the car, the central part of which is large enough to carry a crew of 14 men. The forward and aft parts are formed with a framing of bamboo.

"The screw is carried by the car. The shaft can be easily lifted from the rear and thrown upon a forward support, so that no damage can arise to it, either on departure or arrival. The screw is driven by four men, or by eight men, working at a capstan. The gas-escape valves, of which there are two, are placed at the top of the balloon, immediately over the pendant tubes before spoken of, and through which the cords for working the valves pass into the car. The balloon is made of white silk, weighing about 7 oz. per square yard, with seven thicknesses of caoutchouc superimposed; the envelope also is of white silk. The joints are so arranged that they are stronger than the material itself. On the inner face, three coats of varnish were applied, formed of gelatine, glycerine, pyroligneous acid, and of tannin. Such a varnish is impermeable to hydrogen.

"The balloon, properly called, weighs about half a ton, and the total weight of the whole machine is 1·753 tons. The crew, luggage, provisions, instruments, &c., weigh 1·446 tons. Of ballast, two-thirds of a ton are taken. Collectively, these figures give 3·85 tons, equal to the full ascensional power of the balloon at the ground level.

"M. Dupuy de Lôme had calculated that, with a speed of five miles an hour, the resistance of the balloon in the direction of its main axis would be 24·26 lbs.; and that the speed of the screw should be 21 revolutions per minute to overcome this resistance. This speed could be easily obtained by four men working for half an hour, and being relieved at the end of that time by four others;

with the eight men working together at a capstan, 27 or 28 revolutions could be obtained, which would give a speed of about eight miles an hour.

"The stability assured by the system of suspension adopted is such that, even under the maximum effort of eight men working the screw, the equilibrium was only disturbed half a degree; and a man in walking from one end of the car to the other only affected it by half a degree.

"The apparatus for producing the hydrogen, by the action of diluted sulphuric acid and iron turnings, consists of two batteries of 40 casks each, producing at one operation, lasting three hours, 5375 cubic feet of hydrogen, and working alternately.

"At the trial trip three days were required to fill the balloon. It was ready on the 1st of February, in the evening, and it was kept inflated all night, but at two in the morning it was allowed to ascend sufficiently to attach the car, rudder, fan, connexions, &c. The loss of gas during the night had been inappreciable, and previous experiments showed that the varnished silk was perfectly reliable. The wind had risen, and the meteorological bulletins were far from being encouraging. However, the inventor decided to make the ascent, and after having repaired a slight damage, he left the ground at 1 p.m.

"There was about two-thirds of a ton of ballast on board, and the balloon was in perfect equilibrium. Three hundred and fifty pounds of ballast were thrown out, and the ascending force thus produced carried the balloon up rapidly.

"A strong wind was blowing from the south. A few minutes after the departure, the shaft of the screw was lowered upon its bearing, and was started by the eight men together, slowly at first, and then with an increased speed. The rudder was first moved to the right and then to the left, and then was adjusted in order to ascertain how far its influence would be felt by the balloon. When the screw was set in motion, the effect of the rudder was immediately felt as desired, proving that the balloon had acquired a sufficient speed with relation to the surrounding air.

"The experimental trip had a threefold purpose: to ascertain the stability of the balloon, the relative speed that could be obtained, and the manner in which it obeyed the rudder, either on a fixed course or in tacking. An anemometer, previously regulated, gave the relative speed of the balloon; a compass attached to the car indicated the direction of movement. To measure the course followed in relation to the ground, a planchette was fixed to the side of the compass, parallel to the vertical plane, and in the direction of the true north. The field of the planchette was painted black, the part forming a vertical surface being white. By this arrangement it was very easy to obtain a visual ray in a vertical plane, the verticality of the planchette being assured by the mode in which the compass was hung. By observing any clearly defined object on the ground passing beneath the observer, and then by turning the planchette in the direction of the same object when it was shifted from the vertical plane, the direction of the route followed by the balloon could be read direct off the compass.

"The same observation gives the speed of the balloon, the height being observed by a barometer.

"Between 1.15 p.m. and 2.35 p.m., eight observations were taken of the height of the balloon, of the temperature, of the route measured on the ground in relation to the magnetic meridian, four times with the screw not working, and four times whilst it was being driven by eight men. At 2·35 p.m., it was resolved to descend, and at 3 p.m. the balloon touched ground at Mondécourt, exactly at the village indicated on the map of the route laid out beforehand, from the calculated deductions of direction and of speed.

"The landing was effected with perfect success and without accident, in spite of the force of the wind. M. Dupuy de Lôme arrives at the following conclusions from the results of the trial. That the stability of the balloon was perfect; that it manifested no signs of oscillation under the action of the eight men working the screw; and that the shifting of the weight in the car produced no sensible movement. The vertical axis was only shifted, under the most trying conditions, a small part of a degree, and longitudinally there was no change.

"In comparing the direction of the balloon drifting freely before the wind, with the direction given to it when the screw was in operation, it was found that the resultant made with the normal direction an angle of 12 deg. It is stated also that the speed given to the balloon with 27½ revolutions of the screw, was 6½ miles an hour, whilst the rate due to the wind alone was from 26 to 37 miles an hour.

"With the same weight for a mechanical motor as that required by the eight men for driving the screw, a force ten times as great might have been obtained, and the speed due to the balloon under such improved conditions would be 13·60 miles per hour. With such a power it would apparently be practicable not only to make a considerable angle with the wind's direction, but also under favourable circumstances to shape the course of the balloon according to will."

In conclusion, I would remark, for the information of those who may wish to pursue this subject, that an excellent account of M. Dupuy de Lôme's balloon is given in the "Revue Maritime et Coloniale," for August, 1872.

G. E. G.

London,
22nd December, 1872.

PAPER XII.

ON PIONEER LABOUR.

By CAPTAIN GUN, R.E.

The subject of military labour as applied to works executed under the War Department, is one which has continually in past years cropped up, and a great number of experiences have been obtained in it, and many papers and statistics collected and published on the subject in the Professional and other Papers. It was held, even a short time ago, by very many, that it was almost a duty to find some so-called profitable work for soldiers in their leisure time, and this leisure time was to be increased at the expense of their military duties. Now, I think, opinion has veered round a good deal lately on this point; the great war of 1870-71, has taught people that a soldier has so much to learn in order to become an efficient, that work as a labourer or artizan cannot be expected of him; the short service lately introduced into the army, has, no doubt, further strengthened this view; and it is hardly possible, therefore, now-a-days to look to the soldier of the Line for much aid in carrying out public works. I am not about to re-open in any way this part of the question: what I wish to bring under the notice of my brother officers is the much smaller question of the use and application of pioneer labour, that is, the work to be got from the small body of eight pioneers attached to each battalion of the Guards and Line, and this only so far as it can be applied to the maintenance and repair of barracks —the barracks, that is, in which their regiment is quartered for the time being.

One of the best essays we have had on this branch of the subject was the lecture given by Major Webber, R.E., at the United Service Institution, in 1869. In that lecture he showed the complicated nature of the proper work involved in carrying out what are termed the "incidental repairs" of a barrack, and proposed as a substitute the employment of soldier labour as a means of simplifying the mode of performing these repairs, and of obtaining their more speedy execution. All who are interested in the subject should read the valuable collection of facts and figures put together in that paper.

In 1870, the question was, for the first time, officially investigated by an army committee, of which Lieut. Colonel Ewart, C.B., was the Royal Engineer member. The deliberations of this committee led to the issue of a circular, dated 30th Nov., 1870, by which the constitution and duties of the pioneers were completely altered. Up to that time these men had been employed chiefly in the fatigue duties of the barracks, in cleaning and dusting, under the Quartermaster of their regiment.

The circular directed the pioneer force to consist of—

"1 N.C. Officer, an artificer—a carpenter if possible—
to be able to write legibly and keep accounts.
3 Carpenters.
2 Bricklayers (one able to plaster, one to slate).
1 Smith (able to shoe horses).
1 Mason (able to cut stone).
1 Painter and glazier.
1 Plumber and gas-fitter.

"Pioneers are not to be required to perform fatigue duties or to serve in the Quartermaster's Stores; they are to be considered as the regimental artificers."

Previously to the issue of this circular, two others bearing on the same subject had been issued: one dated 1st Oct., 1869, clause 136, which directed the issue of "tools," to be kept in charge of regiments, and inspected periodically by Commanding Royal Engineers; the other, Army Circular, July, 1870, clause 89, which specified rates of working pay to be allowed, and in par. 25, enjoined, where practicable, the payment by piece or task work.

These, it will be seen, made a great alteration; from that time, there became available in each battalion a small force of artificers sufficient to do all the works of maintenance, and in addition, in some cases, some of the smaller new services in a barrack, just such as our own men of the Royal Engineers are accustomed to carry out, wherever they are stationed.

What I want to bring under the notice of the corps is the work in which the system has been tried in one District, the Home, where Guards' battalions alone are quartered, and where it has been in operation to some extent for three years.

The most complete trial has been given to the system at Windsor, in the Home District. At that station are quartered a Battalion of the Guards and a Regiment of Household Cavalry, and the barracks they occupy are the most complete, perhaps, in the kingdom, and give rise to as large an average of incidental repairs as any new buildings of the sort at any station. Without going into long columns of figures, I may state that the eight Pioneers of the Guards' battalion have done fully 80 per cent. of the "Quarterly Requisitions" and "Immediate Repairs," arising in *both* the barracks, but have not done any of the new services, or of those known as Part 3 services, being the larger works of maintenance. The battalions and their pioneers are changed every six months, and the seven, constituting the Brigade of Guards, have all passed through the garrison in the time referred to.

It has been found, as might be expected, that the quality of the artificers was unequal in different battalions, but that *one* good plumber, *one* good bricklayer, and *two* good carpenters, could be counted on in each. In general the sergeant or corporal in charge was a man of sufficient knowledge and intelligence to direct the work under the military Foreman of Works, who is a Royal Engineer sergeant. In London the system has only been on trial, to any extent, for a year, and pretty much the same result as above has been arrived at. It may, I think, therefore, be established, that the pioneers of a battalion can keep a barrack in repair in about half their time, seeing that they are able to undertake two barracks when fully employed.

In working out the details of the system, two modes of payment of the men can be adopted, and each has been tried. By the first and simplest the men are paid by the hour, and the materials supplied to them from the Royal Engineer store, being delivered there by the War Department contractor. It is obvious to those acquainted with the book-keeping of a Royal Engineer office, that this plan does away with pretty nearly the whole of the authorised system of keeping accounts. The expenditure on particular items, which is the essential feature of these accounts, is not thereby recorded, and a general result can only be known at the end of the quarter or year. The other plan consists in adhering to the system of accounts, that is, in "detailing" the work to be done by pioneers, and ordering it on the same plan as if a contractor were employed. In this case the party, not the individual men, get the money earned.

I append a requisition, showing the mode of estimating thus employed; at the foot of the requisition is an abstract, by which a deduction is made from the value of the work, so as to effect the saving that should be obtained from military labour. It will be seen that the cost of the materials used is first deducted from the total value of the work, and it thence follows that the more material a man uses, the less money comes to his party. This tends, on the whole, I think, to good work.

This mode of paying for work has the advantage of securing a certain gain to the public, and of keeping all the accounts in the form sanctioned by long usage.

The War Department system of carrying out repairs in barracks has always been by piece-work when a contractor is employed, and, worked as above, it remains so when the pioneers do the services instead.

The sergeant of pioneers is employed on *day*-work, so that he may give his time to superintendence, drawing materials, and measuring repairs; the success of the plan turns almost entirely on the qualifications of this non-commissioned officer. If he is unintelligent and unskilled, the military Foreman of Works has to do his work, *i e.*, to do what falls to a contractor's foreman, in addition to his own, and the labour thrown on him is excessive. On the contrary, with a good sergeant of pioneers, the repairs are put in hand quickly, and everything runs very smooth.

I am not prepared to say that, at present, all the sergeants of pioneers that I have seen are up to the work, but I think that they ought to be in a certain time, if continually employed. In these last words lies the difficulty. My own experience is that a pioneer party of the Guards can become very efficient in six months if employed constantly, but can forget all they have learnt if away at some other place for a year or two where they have nothing of the sort to do. Hence, my first deduction is, that in every barrack in or out of the kingdom, the pioneers should, as a matter of course, do the greater part of the repairs. It must be remembered that these are only a small part of the War Department work of the year; all the "Part 1," "Part 2," "Part 3" services remain to be carried out by Royal Engineer civil labour, but the small repairs known to us all as "incidentals," are those on which the comfort of the soldier greatly depends, and which can best be done by men constantly resident inside the walls.

Secondly. There should be in every barrack a pioneer workshop, in charge of the regiment. This shop should have a forge, a carpenter's and a plumber's bench, and may be about 20 ft. by 15 ft. It should be a detached building, so as not to endanger the barrack in the case of shavings and chips catching fire. In this shop would be carried out the Engineer repairs, the control services, and anything the regiment may have to be done by the pioneers.

Thirdly. The pioneers must all be "good" artificers. It is by no means certain that it will be practicable to obtain eight such out of an ordinary battalion; hence, it may be necessary to enlist them specially as artificers, as the Royal Engineers are enlisted. With the prospect of *constant* employment, this would be an easy thing to do.

I have not touched upon the value of such a body of pioneers in time of war. It is well known to all students of military operations, that at every turn and twist, artificers are required to carry them out. Only note what the Prussians do in this matter. A battalion of 1,000 pioneers is attached to each of their corps d'armée. On this scale there ought to have been ten full companies of Engineers at the autumn manœuvres of the past year; failing such a strength as this, would the two or three hundred pioneers that would be scattered amongst 30,000 men be out of place?

To sum up, therefore, the pioneers of battalions of Infantry should be good artificers; their non-commissioned officer should be a superior artificer, equal in skill to our best Royal Engineer full-corporals or sergeants; they should be always employed in peace time in the repairs of their own barracks; and a good workshop should be at their disposal. They can be paid either by the day or by piece-work, and the latter system saves a certain definite per-centage in the estimates of the year, avoids all the difficulties of classifying men by skill, and enables the accounts to be presented in the authorized manner. A great deal has been said on the complications of this, the authorized system, of accounts, but I doubt if method is ever thrown away, and whether, after all, when intelligently worked, a better can be devised. At any rate, whatever improvements can be made in it can as well be made in keeping the accounts of the pioneers.

H. A. G.

APPENDIX.

Immediate. No. 1.—Req. 1. W. O. Form 1486.

REQUISITION for IMMEDIATE AND URGENT Repairs, arising from fair wear and tear, to the Buildings in charge of the 120th Regiment at Pontypool (Royal Barracks).

Item.	Name of Building and Room.	Nature of Repair required.
1	Women's Wash-house	Repair Bench or Form
2	E. No. 7 Room	Repair Floor
3	E. No. 10 Room	Repair Floor
4	B. 3. Kitchen No. 5	Repair Lock to Door
5	C. Women's Latrine	Repair Valve

We certify that the above Repairs have become necessary through fair wear and tear, and not through any neglect or wantonness on the part of the occupants; that they are fairly chargeable to the Public; and, further, that they cannot be postponed until the next quarterly inspection without serious inconvenience.

Signature of Officer Commanding or in Charge of the Department ... } A.B., Lt.-Col., Comdg. 120th.

Date, 1st Feb., 1873.

Signtre. of N.C. Officer R.E.D. making the Inspection, C.D., Serg., R.E.

Date, 2nd Feb., 1873.

Received in Royal Engineer Office, 2nd Feb., 1873, Execute immediately, with the exception of Items —, which may be postponed, for the reasons stated against them. The expense to be reported as soon as it can be ascertained.

Signature, E.F., Lieut., R.E.

Date, 3rd Feb., 1873.

DETAIL OF EXPENSES INCURRED.

Item and part of Building.	Description of Work.	N.	L.	B.	D.	C.	Price.	Item of Schedule.	Triennial Contract.	Military Labour. Piece-work.
							s. d.		£ s. d.	£ s. d.
1. Women's Wash-ho.	Repairing bench—									
	Carpenter	½ day	...	...	...	...	5 6	548	....	0 2 9
	2-in. deal, S.O.	¾ ft.	...	...	...	¾	0 4¾	39	....	0 0 3½
	1-in. deal, S.O.	½ ft.	...	...	...	½	0 2¾	,,	....	0 0 1½
	Clasp nails, 7 to 12	1 lb.	...	...	...	1	0 4	746	....	0 0 4
2. E. Room 7	Cutting up old deal floor under 4-ft.	1	...	...	...	1	0 4	436	....	0 0 4
Near W.I.......	1¼-in. deal, wrought O.S. and fixing	1	4.0	7	...	2.4	0 5¾	160	....	0 1 1
3. E. Room 10	Cutting up old deal floor	1	6.6	1.9	...	11.5	0 1	435	....	0 0 11½
	1¼-in. deal, wrought O.S. and fixing	1	6.6	1.9	...	11.5	0 5¾	160	....	0 6 0
4. B. 3. Kitchen 5 ...	8-in. iron rim dead-shot lock, and fixing in repairs..........................	1	...	...	...	1	7 1	697	0 7 1	....
	Letters engraved	9	...	...	...	9	0 0½	617	0 0 4½	....
5. C. Women's Latrn.	Repairing valve and lifter, refixing, &c.—									
	Plumber and labourer.	½ day	...	...	...	½	9 0	275/276	....	0 4 6
	Solder, tinning	½ lb.	...	...	...	½	1 0	267	....	0 0 6
	Sheet copper	¼ lb.	..	...	...	¼	1 4	229	....	0 0 4
									0 7 5½	0 17 2½

Approved, chargeable to Item 70 of the B.A. Estimate for 1873-4.

G. H., Commanding Royal Engineer.
Date, 17th April, 1873.

ABSTRACT.

	s. d.	s. d.
T. C.		7 5½
M. L.	17 2½	
Less materials......	5 10¾	
	2) 11 3¾	
	5 8	due to Soldiers.

No. 2.

Quarterly Account of Military Labour.

Midland District, Royal Barrack, Pontypool. Quarter ending 31st March, 1873.

No. of Requisition.	Value of Work.	Value of Materials.	Balance remaining.	Proportion ·5 due to Soldiers.	Day Work.	Payments on account.	Date.	Remarks.
	£ s. d.	s. d.	£ s. d.	£ s. d.		£ s. d.	d. m.	
1	0 17 2½	5 10¾	0 11 3¾	0 5 8		0 7 0	7 2	
2	3 0 0	12 11	2 7 1	1 3 6½		1 0 0	14 2	
						0 2 2½	21 2	
				1 9 2½		1 9 2½		
Superintending N.C.O. of Trades......					7s.			Proportion of total amount due to Suptdg. N.C.O.

No. 3.

Requisition.	Materials.	No.	Price.	£	s.	d.
	Requisition 1. R. B., Pontypool.					
	2 inch deal .... ft.	1	4¾			4¾
	Clasp nails .... lbs.	1	4			4
	1¼ inch deal .... ft.	10	5		4	2
	Solder, tinning .... lb.	1	...		1	0
					5	10¾
	Requisition 2. R. B., Pontypool.					
	.... ft.	2	6		1	0
	.... lbs.	1	3		0	3
	.... ft.	20	7		11	8
					12	11
	Requisition 4. Granby Barracks.					
	.... ft.	3	9		2	3
	.... lbs.	7	2		1	2
					3	5

EXPLANATION OF TERMS IN APPENDIX.

No. 1 is the ordinary intermediate Requisition Form. It will be seen that the usual mode of estimating is employed.

No. 2 is the Quarterly Return furnished with the requisitions and Contractor's Bills to the War Office. It is an explanatory summary of the payments on account shown in column 7.

No. 3 is a specimen page of the Store Issue Book.

It will be seen that Requisition 1 is carried through the three forms. It will be noticed that the materials drawn by the pioneers are not the same that are absolutely required for the particular requisition ; they appear to have some of the things in hand left over from another requisition.

PAPER XIII.

ON SIEGES.

By KRAFT, PRINCE OF HOHENLOHE-INGELFINGEN,
Major General, Inspector of the IInd Artillery Inspection.

Translated from the German
By CAPTAIN F. C. H. CLARKE, R.A.,
topographical staff.

Introduction.

There are a great many instructive lessons to be gained by a study of the attack and defenee of fortresses in the last campaign. Twenty fortresses in all surrendered to the German arms, and there were only two which were not reduced—viz., Langres, which was masked, and Bitsch, which, from its position, did not allow of a serious attack in form.

The twenty sieges, which were continued until the surrender of the fortresses, exemplify practically all the different conditions with which the science of the subject had made us acquainted, from the blockade and the surprise to the regular formal siege. Although the information at present available is not sufficiently detailed to admit of the construction of any definite theory with regard to the future conduct of sieges, yet it is very certain that the method of siege hitherto in force is no longer applicable in the present day. Consequently, everyone who reflects on these matters forms his own opinion on what should be done in future, and bases it on all he has experienced, heard, or read during the last war.

In the following pages I will give my views on this subject, but first of all would premise that they have no claim to be considered complete, and from the insufficiency of my own knowledge of many of the facts of the last campaign, they must be subject to change. I would further remark that I have assumed the existing siege *matériel* as the type, and have refrained from speculating upon any new inventions, so as to confine myself exclusively to the subject under its present conditions.

Investment.

Before the siege of a fortress can be resolved upon, we must be victorious in the field; and in order to be able to capture the fortress, either a numerical or moral superiority is necessary on the part of the besieger.

After this victory in the field has been gained, the besieger may march upon the fortress with the intention of opening the siege; but before the siege *matériel* can be brought up and arranged with a view to commencing the attack, the fortress must be invested on all sides.

If the defender is capable of assuming the offensive, he will endeavour to hold as much of the ground in front of the fortress as possible, so that the armament of his batteries may be completed with the least molestation from the enemy's fire, and he will occupy and intrench himself temporarily on any points which may be suitable. The besieger will endeavour to prevent him from doing so, and to throw him back into his works. Engagements in the field on a larger or smaller scale will ensue, terminating with the investment of the fortress. To effect this the besieger establishes himself firmly on those positions offered by the ground, entrenches himself with his field guns within temporary fortifications, and thus cuts off the defender's communication with the surrounding country.

The theoretical question then arises, "Where, and at what distance from the works of the fortress, should these positions be selected?" In practice, this question has received many different solutions. On many occasions the positions were so close that the siege artillery commenced its fire for the reduction of the fortress as soon as it was mounted in them; others were at a greater distance. In reality, the choice of position is dependent partly on the ground, partly on the energy with which the defence is conducted.

There can be no question that an energetic besieger, merely from his superiority, should be able to throw back the defender into his lines, even if in so doing his numerous field guns be involved in a struggle against the enemy's garrison guns as long as the investing process lasts; the field artillery meets with some loss, but will certainly not be annihilated. But it is another question whether we can maintain ourselves in this position for the requisite time without being exposed to great loss in consequence of the close proximity of the garrison guns, and also to the excessive exertion consequent on a perpetual state of readiness for battle, and thereby endangering the result of the siege; for field artillery lacks the requisite ammunition to keep up a constant fire day and night. If the siege artillery, with the necessary supply of ammunition, be at hand, so that it can be placed in position and be in readiness to open fire in one or two days, then we should hold provisionally with our field guns those positions which we have won by throwing the enemy back on the fortress. This is, however, only very exceptionally the case. On the contrary, days—even weeks—may pass before the first shot from a siege gun is fired, and until then we cannot engage our field troops within the most effective ranges of the fortress. Consequently, less forward positions are sought for, and only the outposts are left in front, their supports and reserves being drawn back more or less according to the ground.

There is nothing to prevent the defender from now driving in our outposts on the main position, in order to re-establish himself in front of the fortress. The besieger should oppose this, and throw him back into the fortress. In doing so, many engagements, more or less severe, will take place, which, unless the defender has lost all energy, must be pushed to such an extent that the latter is only allowed to occupy so much of the ground in front of the fortress which, if occupied by the besieger, would expose the main body of the out-posts to the fire of the artillery of the fortress.

It may be assumed, therefore, that the defender finally succeeds in pushing forward his out-posts to a distance of from 1000 to 2000 paces beyond the fortress, whilst the besieger's line of outposts can seldom hold its position within 3000 paces, and as a rule is even further distant. In short, the besieger eventually remains at a distance of from 2500 to 4000 paces.

Instances have occurred in the last campaign where the defender has scarcely ventured out of the fortress after its investment, and the besieger has been thereby enabled to establish his first batteries within 1800 paces. We will, however, in theory assume that we are opposed to an enemy capable of an energetic defence.

Choice of the Front of Attack.

During the investment and the engagements resulting therefrom, a reconnaissance is made of the fortress, for the purpose of selecting the front on which the attack is to be directed. In this matter, certain points due to recent inventions, which in no way affected former sieges, are of decisive moment.

Firstly, the *matériel* which is used in sieges is so considerable that it is of great importance to have posession of a railway leading from the base of operations to the siege park. Not only the weight of the guns, but still more the weight of ammunition expended daily, which has to be replenished from the rear, day by day, make this means of communication very desirable. (At Paris nearly 3000 *centners** of ammunition were fired away daily; at Strasburg a still greater number).

The situation of the railway at our disposal will, therefore, have considerable influence on the choice of the front of attack, especially in large fortresses; and it may happen that we may prefer to attack a stronger front because our work will be made easier by the greater abundance of *matériel* brought by railway, than a weaker front which has to be supplied by land transport. In smaller fortresses this question is in certain cases of less importance—if, for instance, the road leading past them is not too far distant and inconvenient. But the larger the fortress, the more important the question; and it may be asserted that a large fortress favourably situated, which has all the resources of art at its disposal and is well defended, can only be captured by a regular attack if the besieger has a railway available, because he can by its means alone provide a superiority of *matériel* over the enemy.

Another point which has recently affected the choice of the front to be attacked, is the increased effect of our guns, both as regards their range and destructive power. Hitherto, those fronts which were deemed unassailable were not strongly protected, and works which once commanded the entire

* About 148 tons.

ground in front, can now be themselves commanded from heights to which, on account of their distance, no attention was paid in the original design of the fortress. Besides, all the fortresses at present in existence were not designed to withstand the effect of our modern siege guns. The defender may remedy this evil in time of war by temporary works, and in time of peace by improving the fortresses, but he will not entirely remove it; because no state is sufficiently rich to be able to raze all its fortresses to the ground, and the improvements can never be anything else but patchwork. Moreover, it is no longer possible to hold the ground within range of the guns of the fortress free from cultivation; because this *rayon* has enlarged so much from an extension of the range of the guns, that the state would not have the means to do so. From all that has been said, fronts of fortresses are weakened, as regards their capability of resistance; and where at one time only, perhaps, a single assailable front could be found, we can now find many, and it thus becomes more easy to seek out a front with available railway communication. Hence we see that the relative position of the line of railway carries still more weight in the choice of the front for attack.

Lastly, there is another point which has become of importance in the choice of the front for attack in the present day, and that is the one which we have previously mentioned—the impossibility of holding the ground within range of the guns of the fortress free from cultivation—and that, in consequence of the great effective range of artillery, points and positions can always be found from which the fortress can be bombarded, and in and behind which the besieger can operate unseen by his adversary. The relative situation of such points to the fortress, and the possibility of securing them during the investment, will have great influence in determining the front for attack; and owing to this circumstance, fronts which have been hitherto considered unassailable, are in the present day, the more favourable for attack.

Duties of the Besieging Troops.

The front of attack having been decided upon, the plan of attack must be settled, the necessary preparations made, and the duties of the besieging troops regulated.

As regards the arrangement of duties, next to nothing is prescribed in our regulations and text books, and, consequently, different methods have obtained at the various sieges. As a general rule, the duty of issuing the orders on this subject devolves upon the general in command of the besieging forces; the artilleryman and the engineer, however, may make proposals affecting their respective branches. Field troops are almost always necessary to second the arrangements both of the artilleryman and of the engineer, and the companies of artillery and engineers employed in the siege become fresh additions to the already organised units of troops, and have to be distributed and rationed. If both these matters are arranged by army head-quarters, the general commanding the siege troops becomes burdened with a mass of executive detail which should never be brought before him, because it has nothing whatever to do with the chief duty of directing the siege. Again, much time and power would be thereby wasted, and the danger incurred that many a favourable opportunity might slip by unutilised because it cannot be seized in the nick of time.

For instance, taking the case of a large front of attack, if orders as to rationing and distribution pass from army head-quarters through the senior officer of artillery to the artillery, much time will be lost; and if the engineers and siege artillery have to send in demands to army head-quarters for every man they require from the infantry, they must take into account the time necessary for issuing the order in sending in their requisitions, which in a large body of troops may be as much as forty-eight hours. If it turns out in the course of the siege that the enemy takes a false step, or has become weakened by our fire, this may be turned to account by setting some spades to work; but this will not be possible on the succeeding night, and by the second night the opportunity will probably have passed by, on account of the counter measures of the enemy. The same holds good should the fire of the besieged have pressed heavily upon the besieger at some point or other, necessitating the throwing up of considerable cover for protection; this would have to be left undone until the next night, by which time the whole of the batteries of attack might have been destroyed. Moreover, the artillery and engineer troops employed in the siege are in perpetual conflict with the field troops if they are rationed and distributed by direct orders from army head-quarters.

On many occasions the arrangement has obtained of incorporating the artillery and engineer forces employed in the siege with the tactical unit of the mixed arms (the Division), and assigning them to it for all matters connected with distribution, rationing, jurisdiction, and requisitions for working parties. The Division, which had one or two divisions of artillery under its orders, supplied the working party required by these garrison artillery companies from the field troops, on the principle that the following was the maximum effort of which each man was capable :—one day outpost, the next day working party, the third day rest. If the requisitions for working parties by the siege artillery or engineers were in excess of the amount the Division could supply, taking the foregoing rule into consideration, application was made to their *corps d'armée*, &c., for assistance from the other Divisions. It should here be remarked that the main body of the advanced guard and the reserve to the outposts may be frequently employed perfectly well for throwing up earthworks, when they are not taking part in the relief of the posts—if, for example, the work to be done lies within the *rayon* in which the reserve is posted. A closer union between the siege troops proper and the field troops is established by assigning them to a Division, and a greater interest on the part of the field troops in the progress of the siege works. I would, therefore, always advise such an organisation, and the force of siege artillery should, consequently, only be placed under the direct orders of the general in command when the fortress is so small that the siege army does not exceed the strength of one Division.

The proposed plan, where it was carried out, moreover solved practically, in the most advantageous way, the question of the share borne by the *personnel* and *matériel* of field artillery in sieges; for when the Division commanders did not want their field batteries in positions, the officers, non-commissioned officers, and men were employed to aid the siege artillery; and it frequently happened that a whole field battery, with the aid of a working party of infantry, built a siege battery, and employed its horses in dragging up the guns with which it was to be armed, so that the garrison artillery had only to superintend the armament and serve the guns. If the field artillery of the Division was insufficient, the Division applied to the *corps d'armée,* which gave a working party from the corps artillery.

It ultimately resulted that seven to eight guns per company of siege artillery were permanently kept in action, whereas in those cases where there was no such organisation of the duty, only four guns per company could be maintained. In no case, however, were any men supplied by the field troops for the service of the siege guns, but only officers of field artillery on some occasions.

It is only natural that many circumstances will affect these arrangements differently, and necessitate other measures—as, for instance, in sparsely populated districts, when we spread our cantonments more widely, and in populous districts keep them more closely together; or in a good season, when we can canton, bivouac, and encamp; or in bad weather, when we may have to build huts. At all events, the greatest importance must be attached to an early organisation of the interior duties and of the arrangements for command, so that orders may be carried out as rapidly as possible. Only when this is the case will everything work smoothly, and the siege be conducted with energy. In all former regulations, text-books, and historical accounts of sieges, sufficient value is not attached to organisation; yet the proper conduct of the siege is as much dependent upon it as the correct employment of field troops upon a proper order of march and a well-regulated distribution of troops.

In conclusion, it may be remarked that perfect harmony in the arrangements of the artillery and engineers is pre-supposed. This can only be permanently secured by the daily conference of the commanding officers of the two special arms, and their mutual agreement as to the works to be carried out, and the proposals to be submitted to the general in command of the siege. The importance of having their quarters and offices close together cannot be overrated.

If the troops of the special arms are incorporated with the Divisions, as before mentioned, the senior officers in command of those troops should assume the chief direction of the works, and, like the chief commanders of the engineer corps and of the siege artillery, act in concert by constant personal intercommunication.

Determination of the Plan of Attack.

A detailed plan of attack can no longer be drawn up, and the work of the first night, first day, and so on, predetermined, as in the time of the great Vauban. In consequence of the increased range of fire-arms, we are compelled, in the present day, to remain at such a distance from the fortress, that we are unable to reconnoitre and see all the points bearing upon the problem; and we cannot, in a previous arrangement of the plan of attack, reckon with certainty upon being able to determine the point where the breach is to be made and the fortress stormed. Yet from the very commencement we must have a clear idea in which direction (approximately) we intend to enter the fortress, because the extent of front of the siege works, and the measures for capturing other works, are regulated by it. The situation of the siege park, and the position of the intermediate depôts, &c., are especially guided by it.

The plan of the siege will no longer, as of old, commence with the arrangements for opening the first parallel; for with the present effective range of fire, we cannot now commence by opening a parallel at 800 paces from the fortress, and, on the other hand, the fire at a closer distance is now so annihilating and decisive, that the principal work is done when we arrive within 800 paces, and the decisive result will not be very long delayed when that point is reached. Taking as the starting point the general situation of the intended breach, the plan of the siege is provisionally limited to those steps which have to be taken for opening the first parallel. We shall revert to this when speaking of the conduct of the siege.

Preparations for the Siege.

The preparations which the investing troops must take in hand before the siege artillery arrives, consist chiefly in preparing the brushwood and wood, in forming the siege park and the intermediate depôts; I take for granted that the entrenchments thrown up by the investing troops for securing the line of investment against sorties are not neglected.

The preparation of the brushwood, wood, &c., was undertaken by the siege artillery in very much the old way, the entire working party being detached to a certain point, where they worked under one commander. This arrangement entailed many disadvantages. In the first place, the working party had at times to march some considerable distance to the spot, and their time and energy were thus wasted; again, they were withdrawn from their cantonments and posts, and were consequently not where they would be wanted in the event of a large sortie. The consequences were that working parties could not be told off from the reserves, and therefore much less work was done Lastly, the constant marching off of troops in the direction of the place of work, disclosed the position of the siege park to the enemy.

In consequence of this, the *matériel* in question was provided in a different way at other places. The troops received the order simply to deliver daily so many fascines, so many gabions, &c., at the points where the parks of *matériel* were established; how and when the troops were to work was their affair. This arrangement can be very easily carried out as a part of the previously proposed organization of the whole duty. The places for collecting brushwood should naturally be selected in those cantonments occupied by batteries or companies of field pioneers; the field artillery or field pioneers execute the work, receiving assistance from those infantry cantoned alongside of them. Under these circumstances, everybody is in readiness for fighting. If there is a sortie, and the troops have to fight, their work for this day remains in arrear. The teams of the batteries, hooked into country waggons, transport the *matériel* as it is made to the depôt.

In this way it became possible to collect fascines, &c., on the third day after the issue of the order. On the first day the *matériel* (fascine-trestles, fascine-chokers, &c.) was collected; on the second day the fascines were made, and on the third delivered.

If there are not sufficient men belonging to the siege artillery and engineers available, the field artillery and field pioneers must form temporary park-administrations (*Park-Directionen*) to organise the *matériel*, and to arrange and administer it. The daily quantum to be delivered must be so calculated that all the *matériel* for the first throwing up of the batteries and communications until the last night of the building of the batteries preparatory to opening fire, is held in readiness for use. A reserve of 25 per cent. should be provided against contingencies.

The choice of the point at which the supplies of brushwood are to be delivered is of great importance, as it depends on the place determined for the siege park, and any further transport of the brushwood after it has once been collected to some other place, is a very endless work, which happens just at the time when the teams are more wanted for other purposes, and the course of the siege may be delayed in consequence.

The siege park should be so placed that it is well out of range of the enemy's guns, and should, therefore, as a general rule, be situated not much less than a German mile* from the enemy's most advanced work.

The brushwood depôts are the nearest to the enemy, then comes the gun park (including machines), then the ammunition depôt, and furthest off, the laboratory store and powder magazine. To avoid unnecessary labour in transport, the gun park and the ammunition depôt should be situated close to the railway.

If the siege park lies at some distance from the ground on which we are about to open our attack, it follows that a great many horses are necessary to keep up the communication, and these horses should be exclusively for the use of this park This circumstance, and the necessity of erecting workshops of very varied kinds in connection with the siege park, make it desirable that the park should be situated near some large town which offers sufficient accommodation for men and horses. If this condition cannot be fulfilled, a considerable number of huts must be built.

It is, of course, assumed that the siege park should lie tactically protected—that is to say, behind the most rearward lines of investment—and, when necessary, it should be surrounded with temporary works or field fortifications, so as not to be exposed to a sortie.

Another preparation which can and should be made before the arrival of the siege artillery, is the building of all those batteries which can be built unseen by the enemy (masked).

* A German mile is equal to 4½ miles English, approximately.—Tr.

In consequence of the great distance of the investing troops from the fortress, and the impossibility of reserving all the ground in front of the fortress free from cultivation, there will always be strips and points on which the besieger unseen by the enemy, can build his batteries—of course, within the *rayon* guarded by his outposts. These batteries may, perhaps, be screened from the enemy's view by undulations of ground, walls, gardens, hedges, woods, or what not. All such favourable points, after being reconnoitred, might be marked out as sites, provided that the building of the batteries on those spots tallies with the general plan of attack. Their construction devolves upon the field artillery of the besieging corps, aided by soldiers of the line, in accordance with the before-mentioned organisation.

It is, of course, pre-supposed that the command staff of the siege artillery has by this time arrived, and that the officer in chief command of the siege has approved of the proposals for the sites of the batteries.

It is now time for me to speak, first of all, of the construction of batteries.

Construction of Batteries.

In the twenty sieges of the last campaign, fully 500 batteries were thrown up. The descriptions varied very much. None were built according to the old regulations, or if they were, they had soon to be altered. This involves no reproach upon the regulations, for the effect of guns is now very different from what it was when the regulations were framed. The French, who adhered to their regulations in a most pedantic way, smarted for it bitterly, their batteries being speedily dismounted.

I will now mention the main points of those types of construction which were most commonly used, and in doing so, will suggest any changes which I believe should be recommended for any future siege, and on what occasions they would be desirable.

1. *Usual form of battery.*

A depôt is organised, the batteries are commenced on the first night, the parapets having a considerably greater thickness than in the regulations (minimum thickness of 24 ft.); between every two guns a hollow traverse with a thick covering of earth, or else a bomb-proof screen between every gun; no embrasure, but merely a trough-shaped indentation on the crest, usually scooped out with scrapers; and a covered space for the detachment close at hand, with arrangements for keeping it warm in the winter.

These batteries can not be finished in one night; two at least are required, and more if the ground is difficult. This description of battery is especially to be recommended for those which can be built masked, and are not unmasked until their armament is completed. These batteries will be usually the first which are built, and therefore, if the siege is properly conducted, those which as a rule have to sustain the brunt of the enemy's fire, and they should, consequently, be of the strongest construction. Since they are built masked, they will be built on the worst ground—in woods, gardens, on the sites of buildings, &c.

From experience of these batteries, I should be inclined to recommend the following: —

The coverings of earth should be as thick as possible. If the ground admits of it, the batteries should be made rather more than *sunken;* the hollow traverses should have a considerable covering of earth, otherwise rifled projectiles impinging upon them at high angles of descent go through them. The thickness of earth over the traverses should not be visible above the crest of the battery, or it would facilitate the enemy's aim; consequently, the interior space should be constructed lower than the interior of the battery, provided the drainage arrangements permit of it. The same holds good as regards the shelter for the detachment. On some occasions, wood timbers have been laid from the bomb-proof screen to the parapet, to form a shelter for the detachment. This is a fatal measure, because splinters of wood increase the losses; and again, beams and planks give no protection, and a shell penetrating into the covering has a very bad influence upon the occupiers, as usually there are many men inside, and a man who goes to the place for rest does not like to have his repose disturbed. It is to be recommended, where practicable, that the interior space should be deepened when the battery is finished, and that the platforms alone should remain as they were. The men thereby gain in cover. As a general rule, let them dig as deep as they can. Instances have also occurred where no embrasure-like troughs have been made, but the crest has been sloped from within outwards parallel to the angle of projection of the gun. This is only suitable in light soil, otherwise the rain-water draining from the crest inundates the interior of the battery. It has been found useful to construct, when possible, two expense magazines *(pulver-kammer)* per battery, as in the event of one being blown up the firing need not be suspended.

2. *Siege battery on the field type.*

The above term was applied to those batteries which were made for a certain number of guns by merely throwing up a revetted entrenchment. The guns mounted on siege carriages, fired *en barbette;* they had expense magazines. Such a battery is easily thrown up in a night, but it gives little cover for men and guns, and must be completed on subsequent nights by deepening the interior of the battery, constructing hollow traverses, bomb-proof screens, and shelter places. When the battery was exposed to the enemy's infantry fire, or was under shrapnel fire, the occupants were at times compelled to heighten the crest of the parapet between every two guns by superimposing one, two, or even three layers of fascines. These formed, however, small embrasures, which facilitated the enemy's aim.

As a general rule, this construction of battery was very convenient when it was desirable to open fire quickly, or when the battery had to give a fire in all directions, and when it was exposed to sorties, and no *emplacements* could be established. It is, however, at the same time, necessary to surround the enemy and crush him with a superiority of fire, so thoroughly, that these batteries, constructed with but little cover, may silence him soon after the firing commences, and thus seek their shelter in the effect they produce. If these conditions cannot be fulfilled, such batteries should never be built.

3. *Hastily constructed battery.*

This battery was recommended by the Royal Inspector-General of Artillery before the campaign, and was much employed. It had the disadvantage that it did not permit the direction of fire being shifted upon a different object, to that for which the battery was built, on the first day, whereas, in the battery alluded to in the previous paragraph we can at any time concentrate the whole of the guns on a given point and crush the enemy at that point. On the other hand, the present construction gives more cover from the commencement. On the second or third day, when the battery is completed, this description permits of the direction of the guns being changed at pleasure. The objection was raised in time of peace that too much earth was given by this construction, and more than we knew what to do with. On service there was never enough earth.

I have come to the conclusion that wherever it is possible—that is to say, wherever we can work unseen by the enemy—the first method of construction should be employed. If, when we first place our guns in position, we are compelled to construct other batteries on points visible to the enemy, then these batteries should be built on the third plan, and armed on the same night that we unmask those constructed on the first principle. As a general rule, exposed eminences give favourable ground for working, so that we can reckon upon building and arming those batteries on the same night.

If the nature of the ground renders this mode of proceeding doubtful, a communication to the spot should be constructed soon after the investment. The enemy cannot keep up a constant fire day and night on the communication for the purpose of rendering it impassable. Eventually his fire slackens, and then the besieger prepares and commences the building of his batteries under cover of this communication; so that the completion and armament take only one night.

If we have already considerably weakened and intimidated the enemy with our fire, the second method of construction will be often well suited at a later stage for the more advanced batteries, and may be advantageously employed at the commencement in place of the construction alluded to in this section, when the enemy is well hemmed in, and when we can oppose a great superiority of guns, as by so doing we save the *emplacements* to provide against sorties.

4. *Emplacements against sorties.*

These have not turned out very well when armed with field artillery, as they have only an interior slope 3 ft. in height, and, consequently, lose much of their *matériel* in course of time. It would be better here to employ the 6-pr. siege gun, for which there would otherwise be no use at the commencement of the siege. Later on, when we get nearer to the fortress, *emplacements* for guns are no longer required, as sorties are more effectually repelled by infantry fire. There will also be points where mitrailleuses can be more advantageously placed to resist sorties, especially wherever the enemy, making a sortie, is obliged to select definite lines of advance within their effective range.

In general, I would recommend the following principles being observed :—

In choosing the spot, especially for the first batteries, we must above all things look out for natural screens, for the purpose of deceiving the enemy as to the situation and distance of the batteries. Hedges, fences, undulations of ground, underwood, walls, and houses situated a few hundred yards in front of the batteries make it exceedingly difficult for the enemy to observe the effect of his fire. We have had batteries which the enemy has endeavoured to search out with his fire for days and weeks, but has failed, and they suffered no losses and produced excellent effects.

No opportunity should be neglected of improving the battery and repairing damages when the enemy ceases his fire. The spirit of the Prussian soldier on service is of so aggressive a nature that he prefers fighting in the open to throwing up earthworks. In fortress warfare this predilection must be combated, otherwise we lose too many men.

Well protected posts of observation should be provided for the use of the officers especially, and their propensity for exposing themselves to the enemy's fire should be combated, except when it is absolutely necessary; otherwise we lose too many officers. Although in all arms the per-centage of loss of the officers was high, it was highest of all in the siege artillery.

We should dig down as deeply as possible into the earth, so as to get more protection from the increased amount of earth.

Prettiness of form, smooth slopes, straight faces and crests, are not only useless but dangerous, because they facilitate the enemy in his aim, and in the observation of his shot.

A battery, when it is seen by the enemy for the first time, should appear just like a heap of earth, of which he can make nothing until its fire clears up his doubts.

The Siege Train and Siege Companies.

During the preparations, the siege train and companies arrive. The rate of arrival depends upon the means of transport. The *matériel* is brought up to the park according to the instructions previously mentioned, and the companies organised.

The strength of the siege train and of the siege artillery troops must be decided separately for each fortress, and, strictly speaking, can only be definitely decided when the entire design of the siege is drawn up. The maximum number of guns must be limited to those which can be employed at one time, with an addition of 10 to 20 per cent. as a reserve for guns and carriages dismounted or under repair. The division into whole and half siege trains (sections) is an arrangement for peace administration, and at the same time a practical distribution for estimating in bulk the siege train according to the size of the fortress. For such a portion can be at once set in motion, and having the transport for the guns there is no necessity for waiting the definitive decision upon the plan of the siege, as any further demands which it may entail can be subsequently supplemented.

In the last campaign we have reduced fortresses with a quarter of the normal siege train, and one fortress (Paris) would have required at least three entire Prussian siege trains if we had wished to employ the formal attack for its capture.

As regards calibres, we require the 9 c.m. (6-pr.) for *emplacements* against sorties, and for effecting lodgments on captured works; the 12 c.m. (12-pr.) for closer quarters and wherever this calibre was large enough, because the transport of ammunition is much easier than for the heavier calibres; the long 15 c.m. gun (24-pr.) for sustaining the earlier engagements on a large scale, and especially wherever the greatest striking power and destructive effect is necessary; the short 15 c.m. gun, in the earliest duels against guns, as a gun for high-angle firing and at closer quarters as a gun for high-angle firing and for making breaches by curved fire, and for demolitions; the 21 c.m. mortar for high-angle firing at longer ranges; and smooth-bore mortars only when we have not sufficient numbers of 15 c.m. guns and 21 c.m. mortars. The relative proportions would stand as follows, assuming that smooth-bore mortars are not required:—

	per cent.
21 c.m. mortar	10
9 c.m. gun	10
12 c.m. gun	30
15 c.m. gun (half short, half long)	50

besides some of the captured French mitrailleuses.

Assuming that guns of these calibres are available, and that the previously suggested organisation of the interior duties is adopted, garrison companies would be required in the proportion of 1 to every $7\frac{1}{2}$ guns; and the best arrangement would be, to assign to a company (200 strong) for permanent charge, either 15 c.m. batteries of 6 guns each, 12 c.m. batteries of 8 guns, 21 c.m. batteries of 4 guns, or two 9 c.m. batteries of 6 guns. These remarks are made in anticipation, and they are really questions to be solved by the arrangement of duties in the batteries, or in the course of the siege.

Opening Fire.

When the preparations are completed, and those batteries are constructed by the field artillery, with assistance from the infantry, on sites unseen from the enemy's position, the next point to be attended to is the throwing up of those batteries in view of the enemy, and which have to be armed on the same night in which they are constructed; further, to decide upon how many and which of the batteries first built are to open fire simultaneously, and finally on what object their fire is to be directed.

With regard to the last point, the following first principles hold good:—

1. A simultaneous fire must be opened from all the batteries in the first position. A partial commencement may entail a check, give courage to the enemy,

is at any rate a waste of ammunition, and should therefore be avoided as much as possible.

In order to guard against any misconception, the following points may be noted :—

It has often happened that before opening fire on the fortress, guns which have arrived by successive siege trains have been posted for the time being so as to strengthen the girdle of investment.

These guns might have to take part in resisting the offensive enterprises of the enemy, and their fire cannot be said to be participating in the "opening fire" of the siege artillery, as it serves another purpose.

2. The fire must not be opened before such a supply of ammunition is at hand that we can be certain that there will be no chance of a cessation of fire from any deficiency. No fixed quantity can be laid down, as it will depend upon the relations of the probable daily expenditure of ammunition to the means of transport, and the distance from which it has to be brought. The besieger must, therefore, have such a reserve store of ammunition that there is no chance of his running short before more can be brought from his depôts. This is a very important matter, because a cessation of fire from want of ammunition enables the enemy to repair his damages, and acts, therefore, as a great check.

Great strength of character is required on the part of artillerymen to hold to this principle with unshaken resolution, because everything is impelling them to open fire as soon as possible. No fortress can be taken quickly enough, consequently the whole world clamours for "opening fire," and the world does not think the siege has begun until the thunder of the guns is heard.

The necessary store of ammunition has fluctuated in practice between 300 and 500 rounds per gun.

3. In the earlier maxims upon sieges, a certain number of rounds was laid down for each gun, which had to suffice for the whole siege. This no longer holds good; for if the fortress does not yield after 800 or 1000 rounds per gun, we must go on firing, or else we are beaten off. Measures must, therefore, be taken for keeping up the home manufacture of *matériel*, so that there may be a continuous certain supply to replace expenditure.

It has happened that fortresses have capitulated just as the besieger's stores of ammunition were exhausted, and there was no prospect of a fresh supply. That was a piece of good luck.

It may happen that the besieger has to run the chance of such a piece of luck happening. It must, however, be remembered—and in theory attention should be drawn to the fact—that if this piece of luck does not attend us, and our supplies are insufficiently provided, the enemy will be successful. The consideration as to whether this risk is to be incurred depends mainly on the commander of the army, according to the well known truism of a still better known authority—"First ponder, then risk."

The position of the first batteries will be determined by the ground. I have previously explained that in a defence conducted with energy, the enemy cannot be prevented from establishing his outposts at distances of from 1,000 to 2,000 paces in front of his works, and, consequently, the distance of the first batteries from the works will vary between 2500 and 4000 paces, according to the ground. The batteries are either the long or short 15 c.m. (24-pr.) and 21 c.m. mortar batteries, the number being so regulated that a superiority of fire may be established over the enemy from the first. Where the enemy can be surrounded, and his works enfiladed in their longest line, a smaller number of guns will suffice; where the enemy can only be bombarded by direct fire, a superiority of guns must be striven for. In addition, batteries must be established to drive him away, and prevent him from holding his ground in the front of the fortress; as well as *emplacements* against sorties. For the former purpose, 12 c.m. guns (12-pr.) will answer; for the latter, 9 c.m. guns (6-pr.) and mitrailleuses.

The arrangements for protecting the necessary communications and telegraph stations from the enemy's fire must be completed before fire is opened.

The Night of Armament.

In the night before fire is opened the batteries should be armed, and those batteries not yet ready should also be completed and armed, or newly thrown up and armed. We have been sometimes able to arm batteries in the day time, and to commence this some days before-hand, in consequence of the enemy not being able to see either the battery or the communications to it. In the latter case, it seems desirable to commence with getting up the ammunition, and only to place the guns in position on the last day or on the last night.

The greatest foresight in the arrangements for arming the batteries is necessary, so as to avoid confusion and mistakes during the night march; and every commander of a battery should inspect beforehand very carefully the road which his column has to take, so that no mistake is possible. Especial attention must be paid in those cases where a battery is to be newly built, because mistakes are more likely to occur, and can be less easily rectified.

This undertaking is, generally speaking, more easy in the present day than formerly, owing to the extension of the range of guns; for as our operations embrace wider tracts of ground, the different advancing columns will find a greater variety of roads, and will not jostle one another. Consequently, the undertaking has a far greater chance of succeeding; because the columns are further apart, and the enemy is therefore less likely to remark them. If the wind is favourable, we may reckon with certainty that the enemy's outposts will hear nothing at 1000 or 1500 paces. Even if they remark anything, it is always very questionable whether they correctly interpret the meaning of the noise, and even if they do, the defenders must make a great sortie to destroy the work, and will arrive too late to do so; for their reserves cannot remain under arms all night, and must, therefore, be first alarmed and formed up. The enemy can, consequently, only disturb the works with artillery fire, which fire has to be carried on by night, without the range having been determined by day, and directed upon points about the position of which nothing definite is known. Such a fire at 2500 to 4000 paces can neither disturb the construction of the batteries nor the armament. The only thing which could cause the failure of the undertaking would be a well combined sortie on a large scale in the direction of the siege works, arranged beforehand for the same night as the arming, which could only be the result of some great chance or else of treachery. We cannot reckon upon either. The best protection against treachery would be to spread false but probable rumours as to the front of attack and the night of armament.

The termination of the night is the signal for "opening fire." It is absolutely necessary that the firing should commence as soon as day breaks, or else the enemy sees the unmasked and newly constructed batteries, and commences his fire before we can. But in the engagement now impending the one who commences has a great advantage in being able to observe the first shots without difficulty, and consequently of making the necessary corrections. Any fortified work which is bombarded on two sides and is hit before it can answer the fire, will have great difficulty in retaining sufficient composure to observe the effect of its own projectiles. Let any man realise the confusion of the artillery garrison, suddenly awakened from its morning's sleep by the enemy's fire, and then having to go and serve the guns on a rampart upon which shell and shrapnel are falling like hail.

In these matters, as in war generally, surprise and initiative guarantee half the certainty of success.

On this account a modification in the foregoing principles of opening fire simultaneously from all the guns, may be introduced under certain circumstances. For instance, it may happen that we are disappointed in our calculation about some battery or other not being entirely finished or armed by daybreak. We should lose the advantage of surprise and initiative were we to wait a half or whole day for the last gun before opening fire.

The order for opening fire must be so timed that we can calculate upon all the guns from the first artillery position opening fire simultaneously. When the "opening" is once determined upon, it must be commenced on the appointed day as soon as there is light enough to see and to make corrections, although certain guns or batteries may not perchance be ready.

Duty in the Batteries.

Before the night on which the batteries are armed, precise instructions should be issued by the artillery with regard to the duties in batteries, reliefs, and reserves of ammunition. There are maxims and regulations on this head, but the most important should be determined on the spot, because they must be regulated by circumstances. Attention may here be drawn to some points:—

Reliefs must take place while it is dark, therefore in the evening or early morning. The early morning relief has the advantage that the men get the range by day, and on the succeeding night have got the necessary information both for carrying on the fire by night, and also for any extraordinary occurrences. On the other hand, it entails the disadvantage that the relief gets a disturbed night's rest before it comes on duty for 24 hours. This is especially so in winter, and it then comes so hard upon them that the men cannot hold out for so long when the cantonments are at any distance. Preference should therefore be given in most cases to relieving them in the evening. It is not desirable to relieve all the batteries at the same hour, as the enemy will soon remark the time at which the fire ceases in the evening, and will commence a heavy fire at the time when the double number of men gives him a double number of targets.

The daily expenditure of ammunition should be fixed by an order. A daily allowance of 50 to 60 rounds per gun gives a very brisk fire; more than this has generally not seemed desirable.

Every commander of a battery is held responsible that this expenditure is not exceeded, and he has to justify himself for any larger consumption by an explicit order to that effect, or by some very special circumstance. In order to avoid any cessation of fire, twice the daily consumption is stored in the battery magazines. The men forming the new relief bring with them from the intermediate depôts the prescribed daily allowance to replace the expenditure. If the consumption has varied, the commander of the battery who is relieved reports to that effect, and the next relief brings up a greater or less number of rounds.

The superintendence of duty and telling off of the officers and non-commissioned officers to the batteries, have varied according to opinion, to the requirements of each case, and the number of officers and non-commissioned officers present. At the commencement of a siege there is always a tendency to employ too many officers and non-commissioned officers. The predilection for fighting on the part of those engaged, and the craving for distinction, rather foster it. Officers and non-commissioned officers, however, are much more exposed than the men, because they have to move about to look after and regulate matters and observe the effect of their guns—in short, they have constantly to move about either partly or entirely exposed. Moreover, with their responsibility and the precautionary measures they have to take, they are more mentally engrossed than the men. If too many men are employed at a time, the losses will soon be very heavy, both on account of the enemy's fire and the over exertion, both mental and bodily. It is therefore desirable at the outset to remember that no more of the superior officers and non-commissioned officers should be employed than is absolutely necessary. One officer per battery has been found sufficient to command it; but it has not infrequently happened that a sergeant-major or sergeant has been placed in charge instead of an officer. A field officer, or perhaps a captain as substitute, supervises a group of batteries which from their position and communications permit of this arrangement.

As often happens in life, we have in the last campaign made a virtue of necessity in this respect, and have fallen upon a very useful arrangement which I should like to see retained, even if the necessity should no longer exist. I allude to the circumstance that the artillery received two natures of gun—the 21 c.m. mortar, and the short 15 c.m. gun—which were entirely unknown to the corps, because they were only just introduced by the Experimental Committee. The officers who were acquainted with these guns were sent in consequence to the different sieges to afford instruction in their use, and they supervised the working and service of the guns and made the necessary corrections. They went from battery to battery, and trained them one after the other.

This arrangement of having instructors I would fain see retained, although slightly changed in form, according to the degree of the men's training, and their acquaintance with the gun. By having an instructor attached, like an adjutant, to the field officer of the day, we are enabled to give the command of batteries to individuals who are not thoroughly well up in artillery duties, but who can be relied upon to carry out any orders with which they may be entrusted.

Preparations for the First Parallel.

Subsequent measures will have to be made dependent upon the course of the first day's engagement. They cannot be determined upon theoretically, and in the present day they are more subject to uncertainty than formerly, because we are further from the enemy, and therefore, as a rule, do not have such precise knowledge of him. If our estimation of the enemy proves correct, and our batteries are properly constructed, we shall establish in the course of a few hours a decided superiority over him. At the same time, the batteries told off for the purpose cannonade the enemy's positions outside the fortress, and direct their fire chiefly upon his reserves *(replis)* or upon any buildings in which he may have entrenched himself. The enemy has sometimes been driven back into the fortress by this fire alone, but, as a rule, a special action between the outposts will be necessary before this result can be attained. Whether this action should be undertaken on the first evening, while the impression of the first day's bombardment is fresh, and its effect utilised, or whether further measures are necessary; whether this action is to be simultaneous over the whole front, or partial; whether the enemy is to be thrown back into the fortress, or whether it is more advisable to be satisfied with smaller successes, and gain ground piece by piece, depends so very much upon circumstances, upon the ground, and upon the moral condition of the enemy, as well as upon the impression made by our fire, that no definite rules can be laid down. Only one point must be insisted on in the most absolute way: in all actions the outposts must be provided with a considerable amount of entrenching *matériel*, so as to be able to make good any advantage which they may have gained. Plenty of spades should be taken, because from that time forth the only available means of cover is that which the earth affords. Walls, gardens, fences, hedges, houses, should only be used for communications so that the enemy should not see us. If the enemy finds us out, these objects afford us no cover against his heavy guns, and the *débris* shot away only increases our losses.

If the general in command of the siege deems it advisable to throw back the enemy at once within the lines of the fortress, he will call up the field artillery of the siege troops to take part in the action.

The decision as to whether the one action is preferable, or whether the ground should be gained piece by piece, depends upon circumstances, like all great decisions in war; but if the defender is driven back within his lines by an effective fire from the first artillery position, the investing troops should not allow *him* to re-establish his position again on the ground in front of the fortress, for they are supported by the fire of their siege guns more efficiently than the defender is by the guns of the fortress. Driving him back by a general action offers the great advantage that we advance more quickly ; the only thing of which we must be certain is the success of the action.

Soon after the fire is opened, the besieger will perceive a considerable advantage due to the fire alone. He is able to see and reconnoitre better, because the enemy's attention is entirely taken up by the heavy pressure which the batteries exert upon him, and the enemy's observers are driven away from many points. It will therefore be possible early on the day of the first artillery engagement to form our resolutions as to the details of the subsequent measures we intend to take.

An energetic defender will, before the fire is opened, have determined upon the actions for which he must prepare himself, and have decided upon the points on which he proposes, when the struggle commences, to take up fresh offensive positions as a surprise to the besieger. This will be still more possible if the fortress is surrounded with a girdle of detached forts, between which the defender constructs his batteries. Moreover, we must be prepared for the fact that we have no precise knowledge of the fortress, and the enemy can throw up lines and works which had not been calculated upon. Both of these measures might inform the besieger, either on the first or on one of the following days, that his first artillery position was not sufficient, and that he must build and arm more batteries, until he has finally established a complete superiority. An energetic defender, with fair means at disposal, will be constantly appearing at fresh points with large bodies of artillery, thereby compelling us to build new batteries to crush him ; and in this way he can, according to the means at his disposal, delay the progress of the siege for days, weeks, and months. General von Todleben—the most celebrated defender of the present day—herein lays the whole turning point of the defence, which can only flag in the event of the besieger receiving reinforcements, of which the defender is deprived. In this way the superiority is secured, and the fundamental object established with which we started—the superiority, either material or moral on the part of the besieger ; otherwise there would be no siege.

Our superiority will be shown by the fact of the enemy being brought to silence, because he can no longer maintain himself on the ramparts. Although the fire continues night after night, he will endeavour to renew the fight afresh each morning, but not for any time ; he may fire a few guns here and there in the course of the day, which we shall have to dislodge, but his entire course of action shows that we are gra ually overcoming him.

While this goes on, our outposts are constantly gaining ground forwards, entrenching themselves, and opening up communications from their position to the rear. Opportunities will offer for pushing forward those batteries which in their first position were too far off from their objects, and in consequence have not done much execution; and when the nearer batteries are built and armed, those replaced by the new batteries discontinue their fire.

The First Parallel and the Saps.

By gradually pushing forward the outposts, we gain the ground on which the first parallel is to be thrown up.

The opening of the first parallel was, according to the old regulations, one of the chief operations of the siege ; and many of the working party had to go out in the open, at the risk of being seen by the enemy, and thereby exposed to great loss. I believe that if the attack is opened from the first artillery position, the first parallel can be established with greater certainty and with less loss, as previously suggested, by gradually pushing forward the outposts up to the ground where the first parallel is to be opened, throwing up shelter-trenches between the positions of the outposts, and afterwards lengthening and widening them into the first parallel. In this way the parallel cannot be established in a single night, but the number of outposts must be augmented night after night.

The proposed plan would have another advantage. The more victorious our arms with the offensive and initiative, the more does the tendency towards the offensive pervade our men to the lowest ranks; hence results such an aversion to digging for purposes of defence or for cover, especially among the infantry, that the latter are prone to consider this physically dirty work as mentally dirty—*i.e.*, it is regarded as unworthy of a Prussian, and in the end he would rather storm entrenchments than build them. This idea takes stronger root if the infantry, as a body, is looked upon merely as a number of workmen placed at the disposal of the engineers. The aversion to work diminishes, however, if the outposts, reinforced by whole battalions, regiments, or brigades, if necessary, are charged with carrying out the work, and if, as in the case of the instructors for the artillery, detachments of engineers are divided off among the infantry troops as instructors. Then the whole body of infantry participates in the honour of carrying it out, and takes an interest in it, being nominally connected with it.

I should like to lay down the principle for all further "approaches," that in all cases where it can be done the work should be carried on by pushing forward shelter-trenches, and afterwards connecting them with one another, and that the different sorts of sap (flying or common) should only be used when nothing else would do. In this way the earthworks are advanced more quickly, with less danger, and with fewer losses, especially if the work is carried out under cover of a systematic well-directed fire from riflemen, wall pieces, and artillery. My idea is not new. It is based on numerous experiences of various campaigns, and I only express the wish that it should be made one of the guiding principles, so that it may be left to the judgment of the general in chief command of the siege, who is acquainted with the energy and vigilance of the enemy, whether he prefers to open the parallels by one large action or by successive augmentations of the shelter-trenches.

The distance of the first parallel from the fortress depends upon the result of the pushing forward of the outposts—consequently, upon the energy of the defence, and upon the ground As a general rule, we endeavour to keep up such a vigorous fire from the first parallel with long-range rifles and wall-pieces upon the defender in his works, that his infantry will seldom venture to show themselves with gun in hand. Hence arises the necessity of constructing the first parallel at distances not much over 1000 paces from the fortress. (It is assumed that our infantry is armed with a long-range rifle). In a defence conducted with energy, it is not an easy matter to succeed in establishing the first parallel much nearer than 1000 paces.

The Second Artillery Position.

As soon as sufficient confidence is felt in the protection given by the shelter-trenches which are to form the first parallel, the next step is to establish the batteries of the second artillery position. This second artillery position is necessary, as the first is too far off to guarantee that certainty of hitting necessary for the absolute annihilation of the defensive powers of the besieged. This second artillery position must be more correctly taken up than the first, as regards the situation of the lines and works. It includes batteries for direct, ricochet, and high-angle firing, counter batteries, and batteries for breaching and demolitions.

It must here be remarked that the number of ricochet batteries under the present conditions of artillery and fortification must be very limited, and that almost all batteries have to fulfil different objects, either at first or in course of time; so that it would be well if these names for batteries entirely died out. It would carry us too far to give a special demonstration of this assertion about artillery.

A part of the batteries already pushed forward from the first artillery position will probably form the commencement of the second artillery position; the details as to how and when do not admit of being even hinted at in theory without reference to a special case. In this position the 12 c.m. gun will be chiefly used as a gun for direct and ricochet fire, and the short 15 c.m. gun employed in great numbers for high-angle fire. The 21 c.m. mortar and the long 15 c.m. gun are worked together from the first position, or from the batteries pushed forward from that position.

In constructing the short 15 c.m. batteries for high-angle firing, it should be remembered that some of them will have to form breaches by curved fire and to act as counter batteries or for demolitions with all or part of their guns at a later period of the siege. Batteries of smooth-bore mortars should only be employed when we do not possess a sufficient number of 21 c.m. mortars and short 15 c.m. guns.

The distance at which the second position should be placed will be somewhat less than half the distance of the first; but as its position will depend a great deal on the ground, no definite distance can be laid down. It may here be remarked that when the batteries have to fire over parallels, they should be at least 300 or 400 paces from them, so that our own infantry may not be endangered by pieces of the lead coating or other matter; further, that direct fire above 1600 yards, and curved fire for breaching above 1200 yards, requires a great deal of ammunition to produce any decisive effect. Consequently, some of the batteries should be established in the first parallel. At the same time, it may be remarked that curved fire for breaching at high angles of descent has but slight effect at close distances, in consequence of the small charge; so that the batteries for breaching by curved fire should not be built nearer than 1000 yards on this account. Three or four parallels are established, and the works are pushed forward to the "crowning" under protection of an overwhelming fire from both artillery lines, and from riflemen.

It may happen, but only very seldom if both artillery lines are well placed and work well, that here and there a battery may be necessary between the parallels.

In practice, this was at times necessary when the progress of the siege works so masked some battery that it was absolutely prevented from firing.

The Breach.

As we progress towards the glacis and gain a nearer insight into the works, we can become certain as to the exact position of the breaches, and decide upon the descent into the ditch, and the passage of the ditch. We can also decide if any subterranean warfare is necessary. There is nothing new to be said on this subject.

It will be very exceptionally the case that we are unable to form a breach by curved fire provided we can observe the effects of the firing of the batteries told off for the purpose from our position on the "crowning," or from any other point. Hence it will seldom be necessary to erect batteries on the "crowning." If it should, however, be necessary to form the breach anew, or to keep it open until the passage of the ditch, the 9 c.m. guns (6-pr.) should be employed in the "crowning" batteries, using a greater expenditure of ammunition to produce the necessary effect. We take it for granted that, as a rule, "crowning" batteries are unnecessary, and that curved fire, corrected if need be by observation from the "crowning," will do all that is required.

When the breach, the descent into the ditch, and the passage over the ditch are established, the storming takes place.

Storming of the breach will be very seldom necessary if the work is demolished in a prop r way—bombarded from both artillery positions, and a hail of shrapnel and shell fire kept up—because there will be no enemy close behind it If, moreover, we succeed in keeping the defender from coming to within several hundred yards of the breach by our artillery fire, then, as a rule, we can occupy the breach by a rush, and establish a footing therein.

If there are retrenchments, then the lightest guns should be first of all employed on the captured work.

If there are any detached forts, the siege has to be begun anew from the detached forts against the main enceinte.

Conclusion.

It may be hinted, in conclusion, that when we succeed in constructing a short 21 c.m. gun, the effect from our first artillery position will be considerably increased; and that the construction of a short and light 12 c.m. gun would add to the efficiency of our shell fire, and enable us to substitute it for the 9 c.m. gun. Our whole siege train would thus be reduced to three calibres—12, 15, and 21 c.m.—a simplification which cannot be too highly estimated.

As regards curtailing the length of the artillery attack, we may do so whenever the defective energy of the defender invites us to take leaps in our progress, or if the energy of the enemy is on the wane from physical or moral causes. I also reckon the bombardment as a shortened artillery attack. But the bombardment should only be employed when we are in a position to supplement it immediately by a further artillery attack, should the bombardment alone not lead to a capitulation, as otherwise it leads to the triumph of the enemy.

July, 1872.

PAPER XIV.

STRENGTH OF TIMBER FOR MILITARY BRIDGES.

By LIEUTENANT T. FRASER, R.E.

Although the calculation of the cross-breaking resistance of timber is a simple matter, it is one that takes time, and on active service, at least, there is none to spare. It is, however, often necessary (particularly with a limited choice) to make sure, in a rough way, that each part of a bridge, for instance, may be trusted to do its work.

The following tables have been prepared so as to give this information, either directly or (by reducing all the constants in the formula) with the least amount of calculation. It has been thought best in every case to give the breaking dead load, it being clearly understood that judgment must be used in loading the beam with, say, from one-fifth to one-half this breaking weight, according to the quality of the material, &c., and also that gradually applied live loads be multiplied by $1\frac{1}{2}$, and those suddenly applied by 2, after which the results may be considered and treated as dead loads.

It seldom happens in the case of hasty military bridges that beams are in the condition of truly "fixed beams." In the tables, therefore, they are considered as supported only.

With a view also to diminish risk from mis-use, the central breaking load has been given in preference to the uniformly distributed one, which is, of of course, double the former. For a similar reason, the strength of larch wood (as being about the weakest) has been worked out as the standard of comparison.

The tables for cross breaking resistance have been got from the formula—

$$C\,W\,l = f_\circ \frac{I}{y_\circ} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where W = the breaking dead load in lbs. at the centre

$C = \frac{1}{4}$, in the case of a central load.

l = clear bearing in inches

$f_\circ$ = the modulus of rupture, = 5000 for larch

$\frac{I}{y_\circ} = \frac{\pi r^3}{4}$ for round, and $\frac{b\,d^2}{6}$ for rectangular timber

(r, b, and d being all in inches).

Although the deflection is not often of importance in the cases in question; still, as the labour of calculating is considerable, it has been thought worth while to treat it in a similar manner, using the formula—

$$V = \frac{n'''\,W_1\,C^3}{E\,I} = \frac{n'''}{8} \cdot \frac{W_1\,l^3}{E\,I} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Where W_1 = the given central dead load in lbs.

V = vertical deflection in inches at the centre

l = span in inches

$n''' = \frac{1}{6}$ for supported beam with central load

E = 900,000 for larch.

From (1) $\quad \frac{W\,l}{4} = f_\circ \frac{I}{y_\circ}$

and if $W = \frac{W_1}{n} \quad \frac{W_1}{n} \times \frac{l}{4} = f_\circ \frac{I}{y_\circ}$

$$\therefore \quad \frac{W_1\,l}{I} = \frac{4 \times n \times f_\circ}{y_\circ} = 4n \times 5000 \times \frac{2}{d}$$

as $y_\circ = \frac{d}{2}$ for circular and rectangular sections,

$$\therefore \quad V = \frac{n'''}{8} \times \frac{l^2}{E} \times \frac{n \times 5000 \times 2 \times 4}{d} = \frac{l^2}{48} \times \frac{1}{900000} \times \frac{2n}{d} \times 20000$$

$$= \frac{2n}{d} \times \frac{l^2}{2160}$$

In Table III, the values of $\frac{l^2}{2160}$ have been worked out for spans of from 1 to 40 ft.

For practical purposes it is only necessary to know the deflection that takes place with the safe loads, as for field bridges this deflection is seldom too great. Any one who has ever worked out formula (2) will appreciate the saving in labour that is effected by using Table III.

Explanation of Table I.

Table I. gives the actual dead load in lbs. which will just break a larch spar of given diameter, with a given span, when loaded at the centre and supported at both ends. Thus, a larch spar of 6 in. diameter, and with a span of 15 ft., should just break with 2356·97 lbs.

Explanation of Table II.

In the case of beams of rectangular section, calculation cannot be entirely avoided, but the actual dead load which will just break a larch beam of a given span, when loaded at the centre, is obtained from Table II., by multiplying the number in the table corresponding to the given span by the breadth and square of the depth, both in inches. Thus, a larch beam with a span $= 15$ ft, $b = 3$ in. $d = 6$ in., should break with a dead load at the centre $= 18{\cdot}51 \times 3 \times 6 \times 6 = 1998$ lbs.

Explanation of Table III. Deflection.

A concentrated dead load (provided it be not greater than the safe load) will cause a deflection **V** in inches, in larch beams of the following spans, which will not exceed the quotient got by dividing the number in Table III., corresponding to the given span, by $\frac{d}{2n}$ where d is the vertical depth of the beam ($= 2r$ in the case of round beams) and n is the fraction the load in question is of the breaking load. Thus, for the deflection due to a load which has been taken at a $\frac{1}{4}$ the breaking load, n would $= \frac{1}{4}$, and the divisor would be $2\,d$.

Example.—Deflection of a larch spar of 6 in. diameter and 12 ft. bearing, under a load of $\frac{1}{4}$ the breaking load, would be $\frac{9{\cdot}60}{2 \times 6} = 0{\cdot}8$ in.

Deflection of a beam of larch, under a load of $\frac{1}{3}$ its breaking weight, with bearing of 15 ft. and a section of 3 in. by 6 in. would be

$$15 \div \frac{6}{2 \times \frac{1}{3}} = \frac{15}{9} = 1\tfrac{2}{3} \text{ ins.}$$

The same dead load uniformly distributed, would produce a deflection $= \frac{5}{8}$ ths of that when concentrated.

The safe uniformly distributed load being double the concentrated load, the deflection with it is $1\frac{1}{4}$ times that with the latter.

With beams "fixed" at both ends, the deflections due to the central and to the uniformly distributed loads are respectively $\frac{1}{8}$th and $\frac{1}{24}$th the above.

The deflection of a half round log is about $1\frac{7}{9}$ths that of the whole log, when each is loaded at the centre with the same fractional part of their breaking weight.

Explanation of Table IV.

Table IV. gives the strength to resist cross-breaking, and the amount of deflection of some woods as compared with common larch, with a modulus of rupture f_o, such that when used in formula (1). f_o is equal to 5,000. (See Tables I. and II.) Thus, referring to Table I., the central breaking weight of a larch spar of 6 in. diameter, and with 20 ft. bearing, is 1767·7 lbs; then (Table IV.) a similar log of spruce fir should have a central breaking weight of $1767{\cdot}7 \times 1{\cdot}66 = 2934{\cdot}3$ lbs., 1·66 being the relative strength of spruce.

Again, from Table III., the deflection of this beam under a central load of a quarter the breaking weight would be $\frac{26{\cdot}67}{4 \times 3} = 2{\cdot}22$ inches: had the beam been of ash (Table IV.) its deflection would have been $2{\cdot}22 \times 0{\cdot}62$ ins. $= 1{\cdot}37$ ins.

This table equally applies to rectangular beams; thus referring to Table II., the breaking weight at the centre of a larch beam, with a span of 15 feet, and section = 3 in. × 6 in., would be $= 18{\cdot}51 \times 3 \times 6 \times 6 = 1988$; had this been a Kawrie pontoon baulk of the same dimensions, its central breaking weight would (Table IV.) have been $2{\cdot}2 \times 1998 = 4397$ lbs., 2·2 being the strength of Kawrie as compared with larch. Again (Table III.) the deflection of the larch beam would (with a load = one third the breaking weight or 663 lbs.) have been $15 \times \frac{2}{6 \times 3} = 1{\cdot}66$ ins.; while a similar beam of Riga fir would (Table IV.) have deflected $1{\cdot}66 \times 0{\cdot}6$ ins. $= 0{\cdot}996$ ins., 0·6 being the comparative deflection.

The application of these tables may be extended by recollecting the following points:—

1. For the same span and load the cross-breaking resistance of a square beam, of side $= d$, is 1·7 times that of the round beam of diameter d.

2. A half-round beam has about a quarter the cross-breaking resistance of the whole beam.

3. In the case of beams fixed at both ends and loaded at the centre, the breaking weight is twice that which will break the same supported beam; and the uniformly distributed breaking-weight is $1\frac{1}{2}$ times that with the supported beam.

4. In the case of a beam supported at one end and loaded at the other, the breaking weight is a quarter of that which, were the beam supported at both ends, would break it if at the centre. While the breaking uniform load is a quarter the corresponding uniform load, which would break the beam if supported at both ends.

T. F.

Lieutenants Nixon, Darby, and M. H. G. Goldie, R.E., kindly helped in the calculation of these tables, which were at first of much greater length.

Clear distance, in feet, between points of support (for all the Tables).	TABLE I. The figures in the Columns of Table I. are the number of lbs. of dead weight which, acting at the centre, will just break supported larch poles of given diameter and span.										Clear distance, in feet, between points of support (for all the Tables).	TABLE II. Numbers which multiplied by bd^2 (in inches) gives the B.W. at the centre of a larch beam of given span.	TABLE III. Numbers which divided by $\frac{d}{2n}$ give the deflection in inches of larch beams of the given span, and of depth d inches.
	Diam. 3-in.	Diam. 4-in.	Diam. 5-in.	Diam. 6-in.	Diam. 7-in.	Diam. 8-in.	Diam. 9-in.	Diam. 10-in.	Diam. 11-in.	Diam. 12-in.			
¾	5892·27	13965·90	27279·93	47138·15	74921·80	111738·30	159102·36	218239·85	290495·13	377127·40	¾		
1	4419·32	10474·71	20460·54	35354·56	56192·87	83805·99	119329·99	163684·31	217877·23	282853·19	1	277·80	·06
2	2209·59	5237·35	10230·27	17677·28	28096·43	41902·99	59664·99	81842·15	108938·61	141426·59	2	138·90	·27
3	1473·11	3491·57	6820·18	11784·85	18730·96	27935·33	39776·66	54561·44	72625·74	94284·39	3	92·58	·60
4	1104·08	2618·68	5115·13	8838·64	14048·22	20951·50	29832·50	40921·08	54469·31	70713·30	4	69·45	1·08
5	883·80	2094·94	4092·11	7070·91	11238·57	16762·00	23866·00	32736·86	43575·45	56570·64	5	55·56	1·68
6	736·50	1745·78	3410.09	5892·20	9365·48	13967·66	19888·33	27280·72	36312·87	47142·20	6	42·29	2·40
7	631·33	1496·39	2922·90	5050·65	8027·55	11972·28	17047·14	23383·47	31125·32	40407·60	7	39·69	3·27
8	552·40	1309·38	2557·57	4419·32	7024·11	10475·75	14916·25	20460·54	27234·65	35356·65	8	34·71	4·26
9	491·00	1163·86	2273·39	3928·28	6243·65	9311·78	13258·89	18187·15	24208·59	31428·13	9	30·87	5·40
10	442·00	1047·47	2046·05	3535·46	5619·29	8380·60	11933·00	16368·43	21787·72	28285·32	10	27·78	6·66
11	401·73	952·25	1860·05	3214·05	5108·44	7618·73	10848·18	14880·39	19807·02	25713·93	11	25·26	8·07
12	368·32	872·89	1705·04	2946·10	4682·74	6983·83	9945·00	13640·36	18156·44	23571·90	12	23·16	9·60
13	339·95	805·75	1573·89	2719·58	4322·53	6446·61	9179·23	12591·10	16759·79	21757·94	13	21·36	11·28
14	315·66	748·19	1461·47	2525·32	4013·78	5986·14	8523·58	11691·73	15562·66	20203·80	14	19·83	13·08
15	294·62	698·31	1364·04	2356·97	3746·19	5587·07	7955·33	10912·29	14525·15	18856·88	15	18·51	15·00
16	276·20	654·67	1278·78	2209·65	3512·05	5237·87	7458·12	10230·27	13617·33	17678·32	16	17·37	17·07
17	259·96	616·16	1203·56	2079·68	3305·46	4929·76	7019·41	9628·49	12816·31	16638·42	17	16·35	19·26
18	245·52	581·93	1136·70	1964·14	3121·83	4655·89	6629·44	9093·57	12104·29	15714·07	18	15·42	21·60
19	232·59	551·30	1076·00	1860·77	2957·52	4410·84	6280·53	8614·96	11467·22	14887·01	19	14·61	24·06
20	220·96	523·74	1023·03	1767·73	2809·64	4190·30	5966·50	8184·22	10893·86	14142·66	20	13·89	26·67
21	210·44	498·80	974·32	1683·55	2675.85	3990·76	5682·38	7794·49	10375·11	13469·20	21	13·23	29·40
22	200·88	476·12	930·02	1607·03	2554·22	3809·37	5424·09	7440·22	9903·51	12856·96	22	12·63	32·28
23	192·14	455·42	889·59	1537·15	2443·17	3643·74	5188·26	7116·71	9472·92	12297·96	23	12·10	35·28
24	184·14	436·45	852·52	1473·11	2341·35	3491·92	4972·08	6820·18	9078·22	11785·55	24	11·58	38·40
25	176·77	418·99	818·42	1414·19	2247·70	3352·24	4773·20	6547·37	8715·09	11314·13	25	11·10	41·67
26	169·97	402·87	786·94	1359·79	2161·26	3223·31	4589·61	6295·55	8379·39	10878·97	26	10·68	45·06
27	163·68	387·95	757·80	1309·43	2081·22	3103·92	4419·63	6062·38	8069·53	10476·04	27	10·29	48·60
28	157·83	374·10	730·73	1262·66	2006·89	2993·07	4260·78	5845·87	7781·33	10101·90	28	9·90	52·26
29	152·39	361·20	705·54	1219·30	1937·68	2889·86	4114·83	5644·29	7513·01	9753·56	29	9·57	56·07
30	147·31	349·16	682·02	1178·48	1873·10	2793·53	3977·67	5456·14	7262·57	9428·44	30	9·27	60·00
31	142·56	337·89	660·02	1140·47	1812·67	2703·42	3849·35	5280·14	7028·30	9124·30	31	8·97	64·08
32	138·10	327·33	639·39	1104·83	1756·03	2618·94	3729·06	5115·13	6808·66	8839·16	32	8·67	68·28
33	133·92	317·43	620·02	1071·35	1702·81	2539·57	3616·06	4960·13	6602·34	8571·31	33	8·43	72·60
34	129·98	308·08	601·78	1039·84	1652·73	2464·88	3509·71	4814·24	6408·15	8319·21	34	8·16	77·07
35	126·26	299·28	584·59	1010·13	1605·51	2394·60	3409·43	4676·69	8225·06	8081·52	35	7·95	81·66
36	122·76	290·96	568·35	982·07	1561·00	2327·94	3314·72	4546·79	6052·15	7857·03	36	7·70	86·40
37	119·44	283·10	552·99	955·53	1518·73	2265·03	3222·00	4423·90	5888·57	7644·68	37	7·50	91·26
38	116·30	275·65	538·43	930·38	1478·76	2205·42	3140·26	4307·48	5733·61	7443·51	38	7·29	96·27
39	113·32	268·58	524·63	906·54	1440·34	2148·87	3059·74	4197·03	5586·60	7252·65	39	7·11	101·40
40	110·48	261·87	511·51	883·86	1404·82	2095·15	2983·25	4092·11	5446·94	7071·33	40	6·93	106·65

TABLE IV.

Name of Wood.	Value of f_o which has been used.	Strength to resist Cross Breaking, compared with Larch.	Comparative deflection under same load.	Name of Wood.	Value of f_o which has been used.	Strength to resist Cross Breaking, compared with Larch.	Comparative deflection under same load.
Ash	12,000	2·4	·62	Larch	5,000	1·0	1·0
Beech	10,000	2·0	·66	Locust Wood	11,200	2·24	
Beech, Canadian	12,700	2·54		Mahogany, Honduras	11,500	2·3	·7
Birch, American	9,600	1·9	·72	Ditto, Spanish	7,600	1·5	
Ditto, Common	10,900	2·18	·57	Oak, English and Russian	10,000	2·0	·62
Blue Gum	18,000	3·6		Ditto, Danzig	8,740	1·75	·75
Bullett Tree	19,000	3·8		Ditto, American Red	10,600	2·1	·42
Cedar	7,400	1·5	1·9	Ditto, African	13,500	2·7	·4
Chestnut	10,600	2·12	·7	Pine, Pitch	9,850	1·96	·73
Elm	6,000	1·2	1·28	Ditto, Red	9,000	1·8	·5
Fir, Christiana	12,300	2·46	·5	American Yellow	7,000	1·4	·62
Ditto, Riga	6,600	1·32	·6	Poplar	9,600	1·9	
Ditto, New England	6,600	1·32	·4	Sycamore	9,600	1·9	
Ditto, Spruce	8,300	1·66		Teak, Indian	15,000	3·0	·37
Green Hart	21,500	4·3		Teak, African	15,000	3·0	·4
Hemlock, Candian	7,370	1·47		Willow	6,600	1·32	
Kawrie	11,000	2·2		Water Gum	17,400	3·48	
Lance Wood	17,300	3·46					

PAPER XV.

EXPERIMENTS MADE TO TEST THE STRENGTH OF FASTENINGS FOR THE HASTY REPAIR OF RAILWAY AND OTHER BRIDGES FOR MILITARY PURPOSES.

By LIEUTENANT T. FRASER, R.E.

The fastenings on which the following experiments were made were :—

(1.) Iron dogs.

(2.) Iron spike nails.

(3.) Wooden trenails or pins.

The holding power of these fastenings cannot easily be determined theoretically, and in the case of (1) and (2) at least, little appears to be known about them.

For all three the method of testing was to fasten two pieces of 12 in. by 12 in. fir, or 7 in. by 7 in. oak, at right-angles to each other, and then tear them apart with a known force. In the cases of (2) and (3), these timbers were connected by planks which were spiked or framed together by means of the fastenings under trial. All the timber used was seasoned.

Figs. 1, 2, 3, & 29, Pl. XX., show how the dogs were used, while Figs. 1 to 7, and 25, 28, and 29, explain the way in which the spikes and trenails were tested. The force required for testing was furnished by means of a lever (Figs. 1 and 2) formed of a fir timber, 16 ft. long and of about 13 in. by 13 in. in section. The timber had a piece of bent sheet iron let into it at F, so as to fit an iron bar, which was well greased and acted as a fulcrum. This bar was bedded in a small block of oak, which again rested on a transom, Q.

The transom Q, was supported on both sides by short ends of whole timbers, the bottom ones resting on a pair of timbers H, which bore in rear on pieces of plank K, and in front on a whole timber M, let into the ground to within 2 in. or 3 in. of its top surface. The object of this arrangement was to get nearly the whole pressure on the fulcrum F, to act upon the timber M, which, but for this and its own resistance, might have been pulled out of the ground by the action of the lever. In cases in which much force was required, the distance from F to A wás 13 ft. 9 in., and from F to B, 1 ft. 3 in. In other cases F'A was 11 ft., and F'B, 4 ft.

At A there was a straight iron bar, from which hung two chains with a scale pan S.

At B was fixed a $1\frac{1}{8}$ in. round iron bar with hooks, on which were hung a pair of railway screw couplings. From the lower ends of the couplings hung large hooks, catching the ends of a $1\frac{1}{2}$ in. iron bar, which passed through a 2 in. auger hole about 6 in. below the top of the log N. It would have been difficult without the railway couplings to have worked the machine, as constant adjustment was necessary in order to keep the lever as nearly as possible horizontal.

The weight at A and the preponderance of the beam acted with a considerable leverage at B, and tended to drag the timber N, away from M. The force exerted was the measure of the holding power of the fastenings.

By this arrangement, the holding power, both with and across the grain, was tried at the same time. The logs used for the experiments were in all cases of Riga (Scotch) fir, except in Nos. 19 and 20, when oak blocks were used in the way shown in Fig. 3, by chaining a horizontal block of oak, 7 in. by 7 in. by 2 ft. 6 in., on to the beam M, and standing a vertical block of oak, of the same section, on the horizontal one, so as to correspond with N, the two pieces being connected by the two iron dogs which were being tested. The method of arriving at the force T, exerted in each case, will be shown by the calculations of experiment 1, for iron dogs. The weight of the beam being 43·75 lbs. per foot run. Failure occurred with leverage 11 : 1.

$$\text{Weight at B} \left\{ \begin{array}{lcl} \text{Hooked bar} & = & 10 \text{ lbs.} \\ \text{Block N} & = & 230 \text{ lbs.} \\ \text{Straight bar} & = & 10{\cdot}5 \text{ lbs.} \\ \text{Couplings} & = & 59 \text{ lbs.} \\ \text{4 Hooks} & = & 21{\cdot}5 \text{ lbs.} \end{array} \right\} = 321 \text{ lbs.}$$

$$\text{Weight at A} = 180 \text{ lbs.}$$

Take moments about F,

$$180 \times 13\tfrac{3}{4} + 14\tfrac{1}{4} \times \frac{14\frac{1}{4}}{2} \times 43{\cdot}75 = \text{T} \times 1\tfrac{1}{4} + 1\tfrac{3}{4} \times \frac{1\frac{3}{4}}{2} \times 43{\cdot}75 + 321 \times 1\tfrac{1}{4}$$

where T is the pull in lbs. which tends to draw up the block N;

$$\text{or,} \quad T = 180 \times 11 + 3500 - 321$$
$$= 1980 + 3500 - 321$$
$$= 5159 \text{ lbs.}$$

$$\therefore \text{ for each dog the holding power is } \frac{5159}{2} = 2579{\cdot}5$$

say 2580 lbs.

It will be seen that the preponderance of the beam alone exerts a pull = 3500 lbs. at B. Similarly, with a leverage of 11 : 4, the pull due to the beam alone = 612 lbs.

As a check on these calculations the beam was tested in each of the two positions, as follows:—

First, with leverage of 11 : 1, the scale pan was suspended at B, and loaded with 4514 lbs., when it was found to balance a weight of 76 lbs. at A. By calculation, the effect of 76 lbs. at A, together with the preponderance of the beam $= 76 \times 11 + 3500 = 4236$ lbs., which is less than the pull got by experiment by 272 lbs.

Similarly, with the leverage of 11 : 4, it was found that 1575 lbs. at B, just balanced 350 lbs. at A. By calculation, $350 \times \frac{11}{4} + 612 = 1574$, which corresponds very nearly.

As, however, there was probably some small loss of pull by friction with the higher weights, it has been thought better to use the calculated values for these pulls, though giving slightly less results than those got by testing in each case.

Remarks on iron dogs. Table I. Form of dogs.

The dogs used were made of different qualities of iron, and of the form shown in Fig. 8. This form has the advantage of drawing the two timbers together, whereas if N M were perpendicular to the shank, the timbers would be apt to separate. The spikes were all chisel-pointed. When dogs are used with spikes in planes at right angles to each other, they should have the form of those shown in Figs. 17 and 18, which were the kind used in experiment 15. If the length AB had been less than BC, the shoulder A could not drive home into the hole made by the point C, at a distance = BC from B. The spikes have also to be rounded, because the first one is driven in the position shown dotted in Fig. 28, after which it has to turn in the wood when the second spike is driven. The results showed that the holding power was quite as good with these dogs as with those used for the other experiments. It was found they could be driven with great ease.

Quality of iron.

Good iron is necessary in order that it may bend without defects at N. Thus, in experiment 7, the iron used, when subjected to test, broke with 29,000 lbs. per square in., with no diminution of area, and with crystalline fracture; while the iron of which Nos. 8 to 12 were made, broke with nearly 60,000 lbs. per square inch of section, with a diminution of area = 0·2 or 0·3, and with good fibrous fracture. This fully accounts for the difference in holding power of No. 7 and Nos. 8 and 9. Most of the iron used was of the latter quality; the ½-in. round being particularly good. If the iron be too soft, it is apt to bend, even though not inclined to break.

Length of spikes.

The holding power increases with the length of the spike; thus, in experiments 4 and 5, dogs of the same weight and originally of the same size were used, but in the case of No. 5 the spikes were lengthened to 6 in. and the shank to 14 in., with an increase in holding power of 500 lbs.

Similarly, Nos. 8 and 9 were made alike, and the shanks of No. 8 then drawn out to 14 in., and reduced to ⅝ in. by ⅜ in. in the centre, without affecting the holding power, as may be seen by the results.

It appears from experiment 14, that a length of spike of 5 in., or about ten times the diameter, was sufficient to cause the shank to fail before the spike drew; as, however, the shank failed with only 14,700 lbs. per square inch, its quality must have been defective; and, as shown in experiment 13, 5 in. is not long enough to call the full strength of the dog into play. Again, in experiment 11, when the spikes were eleven times the diameter (⅝ in.), they broke at the shoulder without drawing. From these and other instances it appears that to get the greatest effect, the length of the spikes should be from ten to twelve times the diameter of the bar, when used in soft woods. While from experiment 20, it seems that a length of ten times the diameter is quite enough to secure the full strength in hard woods.

Lightest form of dog.

For military purposes, the lighter the weight of dogs of a given strength the better; thus the dogs used in experiment 13, are lighter and stronger than those in experiment 9.

Quality of wood.

From experiments 19 and 20, it appears that with oak the holding power is about one-third greater than with fir. In this case holes were bored for the spikes in the second experiment. With hard woods, also, there is but little separation of the logs up to the point of breaking. In soft woods, separation commences a good deal below the breaking strain. Thus in experiment 12, the logs had separated 2½ in. before failure. This shows that a factor of safety of at least one-third should be used.

In examples 6 and 17, where fir was used, the lower spikes tore through the horizontal fibres when driven at a distance below BD, Fig. 4, of 5·3 and 5·5 times their diameters. With such spikes, therefore, dogs should be driven at from 7 to 8 times their diameter from that surface of the log towards which they pull. While from experiment 12, it appears that dogs will draw through with the grain when driven 6·4 times their diameter from the end; but at a distance of 8 or 9 times the diameter, this did not occur.

Remarks on iron spikes. Table II.

The experiments on spikes were only tried in fir. In all cases the spikes or groups of spikes were arranged symmetrically with reference to the axis of the block and planks.

Effect of groups. As a rule, the holding power per nail, of a group, appears to be greater than that of single nails.

Thus, in experiment 13, with a group of five, B,W = 1762; while with 14, when only one nail was used, B,W = only 1190. Again, in the case of 9 and 8, 1830 lbs. per nail was given by a group of four, while two only gave 1220.

With thin planks the spikes, if closer to the end than 12 in. to 18 in., are apt to split the wood if driven without holes. With such planks also it is better not to drive the heads into the surface of the wood, as they may draw through.

There is no object in using more spikes than correspond to the tensile strength of the plank. See experiment 13, Table II.

Spikes generally fail by bending, hence it is best to make them thickest at a distance from the head equal the thickness of the plank they are to be used with.

Remarks on wooden trenails. Table III. In testing these trenails no assistance was given to them by wedging or plugging round the holes, though no doubt better results might thereby be got; but as in hasty bridging such precautions might be omitted, it seemed safer to get the results under the most unfavourable conditions. When practicable, however, a vertical saw-cut might be made in the head of the trenail, into which a thin wedge can be driven. This prevents the tendency the planks or cover-plates have towards slipping away from the beams, and thereby cross-breaking instead of shearing the trenails.

In driving, it prevents splitting, if the head of a sledge-hammer be held against the head of the trenail; the first hammer being struck by a second one.

In every case only four trenails were used, one at each point of fixing. The breaking weight being, as in the other cases, that of one trenail. In all cases there was some separation of the logs, owing to the bending of the trenails.

It was found for oak that the holding power per square inch of section did not vary much with the diameter of the trenail. While with fir the larger diameters gave the best results per square inch.

General results. In fir timber the holding power in lbs. is—

For iron dogs, from 600 to 900 lbs., for each inch in length of spike.

For spike nails, from 460 to 730 lbs. per inch in length, exclusive of thickness of cover-plate.

For oak, ash, or beech trenails, 2000 lbs. per square inch of section.

For fir (Scotch), spruce, or elm trenails, from 1000 to 1200 lbs. per sq. inch.

Holding power of spikes in hard wood is increased approximately one-third.

All the trenails were of seasoned wood.

Further experiments with green oak and unseasoned Scotch fir gave a mean holding power per square inch of 2190 lbs. for the oak, and 1500 lbs. for the fir. This seems to show that the holding power of these woods, when green, is at least not much diminished.

T. F.

TABLE I.

IRON DOGS.

No. of Experiment.	Length of Dogs.	Length of spikes.	Section of Iron. Single dimensions are diameters.	Fracture.	Breaking weight in lbs. per dog.	Holding power in lbs. per inch of spike.	Mean holding power in lbs. per inch of spike.	Remarks.
	inches	inches	inches					
1	12	5	$\frac{7}{8}$ by $\frac{7}{8}$	Good	3486	697·2	700	Tore away at N, Fig. 11. The shoulders had been thickened by an extra forging which was defective, hence low result.
2	15	6	$\frac{7}{8}$	Nil	5356	892·6	900	With about 5000 lbs. per dog the logs had separated $1\frac{1}{4}$ ins., owing to fibres of upper log crushing under the spikes. Fracture due to a lower spike bending and drawing; crack as in Fig. 9.
3	16	5	$\frac{3}{4}$ by $\frac{3}{4}$	Nil	3800	760	760	Both bottom spikes drew without breaking, but one cracked at N, Fig. 10.
4	12	5	$\frac{3}{4}$	Fair	4500	900	870 (4–5)	Outer bottom spike opened at shoulder as in Fig. 12.
5	14	6	$\frac{3}{4}$	Fair	5066	844		Dogs 12 in., with 5 in. spikes, same weight as 4. They were then drawn out. Bottom spikes driven 5 in. below top edge of horizontal log. Failed by drawing out; cracked as in Fig. 12.
6	14	6	$\frac{3}{4}$	Nil	3800	..	740 (6–12)	The lower spikes were only 4 in. below top edge of horizontal log, through which they tore without breaking.
7	12	4	$\frac{5}{8}$ by $\frac{5}{8}$	Nil	2580	645		Failed by a lower spike drawing out.
8	14	4	$\frac{5}{8}$ by $\frac{5}{8}$	Nil	3100	775		Reduced, before use, to $\frac{3}{8}$ in. by $\frac{3}{8}$ in. at centre of shank, by being drawn out. Both spikes drew.
9	12	4	$\frac{5}{8}$ by $\frac{5}{8}$	Nil	3103	776		Same as 8, only not drawn out. Spikes drew without breaking.
10	12	5	$\frac{5}{8}$ by $\frac{5}{8}$	Nil	3404	681		Outer lower spike drew.
11	12	7	$\frac{5}{8}$ by $\frac{5}{8}$	Bad weld	5360	766		One upper spike failed as in Fig. 12. There was a flaw from forging at N. Logs separated $2\frac{1}{2}$ in. before failure.
12	12	6	$\frac{5}{8}$ by $\frac{5}{8}$	Nil	4817	803		The upper spikes were driven within 4 in. of foot of vertical log, through which they tore right out to the bottom without breaking.
13	12	5	$\frac{1}{2}$ by $\frac{1}{2}$	Nil	3260	652	610 (13–16)	One lower spike drew.
14	12	5	$\frac{1}{2}$ by $\frac{1}{2}$	Good	2756	551		One upper spike tore away as in Fig. 13. The other as in Fig. 16.
15	12	5	$\frac{1}{2}$ by $\frac{1}{2}$	Good	3080	616		Four twisted dogs used, arranged as in Figs. 28 and 29. One top spike cracked at the shoulder and drew, the others then went.
16	12	4	$\frac{1}{2}$ by $\frac{1}{2}$	Nil	2466	616		One top spike drew without breaking.
17	8	6	$\frac{1}{2}$ by $\frac{1}{2}$	Good	2988	..	..	Inner lower spike drew and cracked, as in Fig. 14. Lower spikes were driven within $2\frac{3}{4}$ ins. of top edge of horizontal log, hence failure and low result.
18	12	4	$\frac{1}{2}$	Fair	2644	661	660	Inner top spike tore off, as in Fig. 13. Fracture a little crystalline.
19	12	4	$\frac{1}{2}$	Bad	3640	910	935 (19–20)	Driven into oak blocks, Fig. 8. The lower one (2 ft. 6 in. long) was split by the spikes, but held together with the chains. Failed by a top spike breaking, as in Fig. 15. No holes were bored.
20	12	5	$\frac{1}{2}$	Good	4800	960		In oak, as before; holes bored with $\frac{1}{4}$ in. bit. One dog broke in driving, and was replaced. Failed by breaking of a top spike, as in Fig. 13. Logs separated very little.

TABLE II.

IRON SPIKES OR NAILS.

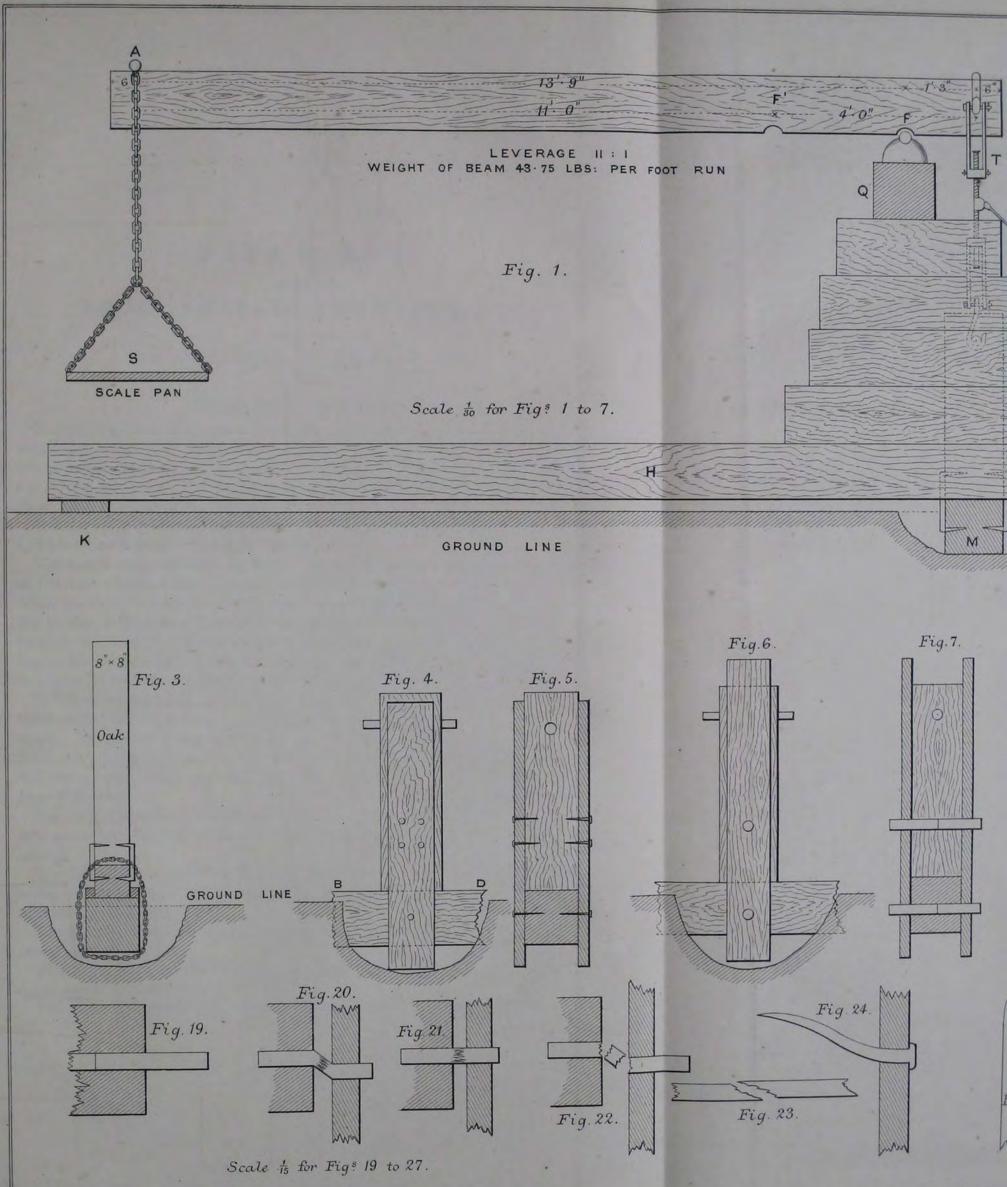
No. of Experiment.	Length in inches.	Weight in Ounces.	Size of Iron.	Number used.	Size of Planks.	Fracture.	Breaking weight (per nail) lbs.	Holding power in lbs. per inch of nail in the solid log.	Remarks.
			inches		inches				
1	10	11·5	$\frac{1}{2}$ by $\frac{1}{2}$	4	3 by 12	Nil	5130	732	Failed by bending and drawing of one upper nail (Fig. 24).
2	9	11·5	Ditto	4	Ditto	Good	3722	472 (rows 2–4)	Failure due to an upper spike dragging through the 3 in. plank, having first bent (Fig. 26). Small holes had been bored for these spikes, but one plank had split at the bottom and was kept together by a dog.
3	9	8·0	Ditto	4	2 by 12	Bad with flaws	2433		A lower spike broke across $3\frac{1}{2}$ in. from the head; fracture showed flaws.
4	9	7·5	Ditto	4	4 by $8\frac{1}{2}$	Indifferent	2240		Both upper spikes drew and broke, one 4 in., the other $6\frac{1}{2}$ in. from the head.
5	8	6·5	Ditto	4	3 by 12	Nil	2190	462 (rows 5–7)	Failed by bending of one bottom spike.
6	8	6·5	Ditto	8	3 by 12	Nil	2413		The two nails in each group were driven in along axis of plank. The upper ones of the lower group being 3in. below BD Fig. 4. Both inner bottom spikes bent and drew.
7	8	6·5	Ditto	4	2 by 11	Nil	2800		One lower spike head drew through the 2 in. plank.
8	7	5·3	$\frac{7}{16}$ by $\frac{7}{16}$	8	2 by 11	Bad Crystalline	1220	..	Arranged as in No. 6, top nails being 21 in. below top of plank. Plank cracked in nailing, and failed by splitting; at same time a lower top nail and two bottom nails broke off $2\frac{1}{2}$ in. from the heads.
9	7	5·3	Ditto	16	2 by 11	Nil	1830	..	Arranged as in upper part of Fig. 4, 3 in. on each side of central line. Failed by splitting horizontal beam, Fig 27.
10	6	4·6	Ditto	16	2 by 12	Nil	2000	555 (rows 10–11)	Arranged as in No. 9, 6 in. vertically between the rows. Upper bottom row 3 in. below BD, Fig. 4. Bottom outer nails all drew together.
11	6	5	Ditto	4	2 by 12	Nil	2440		Failed by drawing of one upper spike.
12	6	1·6	$\frac{3}{16}$ by $\frac{3}{8}$	16	2 by 12	Indifferent	630	157	These were cut nails, arranged in groups of four, as in Fig. 4. Three lower nails broke together, then four upper ones.
13	5	2·5	$\frac{5}{16}$ by $\frac{5}{16}$	20	2 by 12	Nil	1762	492 (rows 13–14)	Failed as in Fig. 25, by a wedge-shaped piece being torn out of the top of one plank, as shewn by the irregular line. The planks were sound Scotch fir.
14	5	2·5	Ditto	4	2 by 12	Nil	1190		Failed by drawing out of one top spike. Holes had been partly bored for the spikes.

TABLE III.

WOODEN PINS OR TRENAILS.

No. of Experiment.	Length of Trenails.	Diameter.	Kind of Wood.	Thickness of Planks.	Length in the Log.	Nature of Fracture.	Breaking weight per trenail, lbs.	Holding power per sq. inch of section, lbs.	Mean holding power per sq. inch of section, lbs.	Remarks.
	inches	inches		inches	inches					
1	15	2	Oak	3	6·5	Cross-breaking	4511			Driven into 2 in. holes, which were rather loose, hence failure occurred by planks partly separating (say 1 in.) from the logs, and the trenails failed by cross-breaking. Fig. 19.
2	12	2	Ditto	3	5	Crushing	7034	2058	2058*	Holes tighter in this case; fibres of one upper pin crushed and split the plank, as in Fig. 21, and drew through the hole.
3	12	1½	Ditto	3	5	....	3505			Holes tighter. Top trenail first to fail, as in Fig. 20.
4	12	1	Ditto	2	6	Crushing	1654			One lower pin crushed first.
5	12	1	Ditto	2	6	Ditto	1794			Two bottom pins crushed and failed.
6	12	1	Ash	2	6	Cross-breaking	1765	2032	2032	Both top pins snapped short.
7	12	1	Ditto	2	6	Ditto	1428			One bottom pin broke, as before. A top one cracked and drew through.
8	12	1	Beech	2	6	Ditto	1610	2050	2050	Bottom inner pin sheered, top outer split. Failure had begun earlier. See Fig. 22.
9	12	1	Elm	2	6	Ditto	804	1023	1023	A bottom one broke short; a top one split. Fig. 23.
10	12	1	Spruce	2	6	Ditto	880	1120	1120	Failed slowly, a bottom one breaking short.
11	15	2	Scotch Fir	3	5	Shearing	5006	1592		Holes tight. One upper one snapt short across, the other drew through 3 in. plank.
12	12	1½	Ditto	3	6	Ditto	2000	1140		A bottom one first snapt short.
13	12	1½	Ditto	3	6	Ditto	2028		1134	Ditto Ditto Ditto
14	12	1	Ditto	2	6	Cross-breaking	880	900		Two bottom ones failed, as in Fig. 22.
15	12	1	Ditto	2	6	Ditto	512			Ditto Ditto Ditto

* This corresponds closely with strength given by Rankine in "Civil Engineering."



A
6
13'·9"
11'·0"
F'
4'·0"
F
7'·3"
6"
T
LEVERAGE 11 : 1
WEIGHT OF BEAM 43·75 LBS: PER FOOT RUN
Q
Fig. 1.
S
SCALE PAN
Scale 1/30 for Figs 1 to 7.
H
K
GROUND LINE
M
8"×8"
Fig. 3.
Oak
GROUND LINE
Fig. 4.
B
D
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 19.
Fig. 20.
Fig. 21.
Fig. 22.
Fig. 23.
Fig. 24.
Scale 1/15 for Figs 19 to 27.

PAPER XVI.

IRON SHIELD EXPERIMENTS.

BY COLONEL T. INGLIS, R.E.

RESISTANCE OF SHIPS' DECKS.

In Paper X., Vol. XX., page 47, it was intimated that further experiments would be made with targets representing the decks of our latest ironclads. The previous trials had been confined to decks covered with 1 in. of iron and 5 in. of fir, and $1\frac{1}{2}$ in. of iron and $4\frac{1}{2}$ in. of fir; the 9 in. 12-ton gun was used in those trials with battering charges, as well as the 13 in. mortar.

For the present trial a target was made which nearly represented the upper and breastwork decks of H.M.S. Thunderer.

The target measured 24 ft. by 14 ft. Half of it represented the strongest part of the upper deck of the ship, or rather that which was originally the upper deck—for there is a forecastle now over a great part of this deck—and the covering of this half consisted of three thicknesses of 1 in. plating, with 4 in. of Dantzic oak over it. The other half represented the deck at the level of the top of the breastwork, which occupies all the midship part of the ship, and was covered with two thicknesses of 1 in. plate, and $3\frac{1}{2}$ in. of Dantzic oak.

The deck beams of the stronger half were of bulb plate, 11 in. deep and $\frac{1}{2}$ in. thick, with two angle-irons on the upper edge, 3 in. by 3 in. by $\frac{1}{2}$ in., spaced 4 ft. apart. The beams of the weaker half were of bulb T irons, 8 in. deep and $\frac{1}{2}$ in. thick, also spaced 4 ft. apart. All the rivets used were $1\frac{1}{8}$ in. diameter, and the oak was fastened with $\frac{7}{8}$ in. and $\frac{3}{4}$ in. screw bolts, tapped into the upper thickness of plating.

The target was placed on the Shoeburyness sands, and was supported on timbers in such a way that its angle of inclination with the horizon could be readily altered.

The line of fire was in the direction of the deck beams, which ran across the width of the target; the beams were supported at their ends only on the timbers before mentioned.

The plating and planking ran transversely to the deck beams, and, therefore, across the line of fire.

Thus, the deck beams had bearings about 13 ft. apart, and, of course, the decks rested on their beams only.

The 10 in. 18-ton and 9 in. 12-ton guns were used in this trial.

Table I., gives the details of the practice; also a diagram, Pl. XXI., showing the shot marks. is given at the end of the paper.

From these it appears that :—

Seven projectiles were fired at and struck the upper deck, namely—

Two 9 in.	(1882, 1884),	at an angle of incidence of	8 deg.
One 9 in.	(1909)	,, ,,	10 deg.
Two 10 in.	(1911, 1912)	,, ,,	8 deg.
Two 10 in.	(1913, 1914)	,, ,,	10 deg.

Six projectiles were fired at and struck the breastwork deck, namely—

Three 9 in.	(1883, 1885, 1886),	at an angle of incidence of	8 deg.
Two 9 in.	(1887, 1908)	,, ,,	10 deg.
One 10 in.	(1910)	,, ,,	8 deg.

No. 1909 struck on the edge of the target, and may be left out of consideration.

The results of the other rounds show that, although actual perforation was in no instance attained, considerable damage was done to the upper deck by those 10 in. shells which burst on impact In one case large fragments of iron were detached from the plating and driven downwards with great force.

The same remarks apply to the rounds against the breastwork deck. Although actual perforation was not attained, the skin was broken through.

As it happened, all the projectiles fired at the breastwork deck ricochetted without exploding. Had the shells burst on impact, the effects would in all probability have been much greater.

It was the opinion of the committee of officers who conducted the trials that that part of the target which represented the upper deck was proof against actual perforation by Palliser shells fired at 10 deg. with battering charges from 9 in. and 10 in. guns, but that greater resistance would have been afforded by the substitution of 1 in. and 2 in. plates for the three 1 in. plates.

It appeared that the effect of a shell striking on, or close to, a girder was less than that of one striking in a space between two girders. The committee therefore thought it probable that the resistance of a deck would be improved by such a disposal of the material as would admit of the number of the deck beams being increased. Also it was thought that the distance between the supports of the deck beams formed an important consideration.

The experiment afforded no evidence with respect to the damage which would be caused to ships' decks by the bursting of large common shells.

The committee considered that there was no practical difference between the results produced by the flat-headed steel and the Palliser shells.

Although some valuable information was derived from this trial it is to be regretted that the target was not on a scale that would admit of a more extended experiment, particularly with the object of gaining data for the construction of roof covering to resist rifled howitzer shells.

Such extraordinary accuracy has been obtained with these howitzers that no doubt high-angle shell fire will take an important part in all future artillery operations.

TABLE I.

SHIP'S DECK TARGET (No. 32A).

Report of Practice on the 19th, 20th, 21st June, and 16th July, 1872.

Range 100 Yards.

Photographic No. of Round.	Gun and Energy of Projectile.	Charge and Brand of Powder. lbs.	PROJECTILE. Nature, Weight, and Length.	Observed Effects.
1882	9 in. rifled M.L., No. 145. Striking energy 3396 foot tons, or 121 foot tons per inch of shot's circumference.	50 P. Pigou & Wilks. August, 1871, lot 847.	Palliser shell, 242 lbs., bursting charge, 4 lbs. 4 ozs., total, 246·25 lbs., 19·1 in.	Angle of incidence, 8 deg. *At upper deck, close to deck beam.*—Struck 4 ft. 7 in. from lower edge of target, 5 ft. 3 in. from right. Graze mark 8 ft. long and 19 in. wide at widest part. Iron exposed 3 ft. 3 in. from beginning of graze for a length of 2 ft. 6 in. *Underneath.* — Bottom plate bulged, and also deck beams slightly so. Two rivets broken in angle iron of the beam on right, and one in angle iron of that on the left of the one nearest graze mark. Crack in this extending to 4 in. from flange, and 1 ft. 10 in. from upper edge of deck. Shell deflected without exploding.
1884	"	"	Flat-headed experimental steel shell, 246 lbs., bursting charge, 5 lbs., total, 251 lbs., 18 in.	Angle of incidence, 8 deg. *At upper deck, between deck beams.*—Struck 4 ft. from upper edge, 6 ft. 6 in. from right. Graze 2 ft. 1 in. wide at widest part. Iron exposed 2 ft. 6 in. from commencement of graze. Shell bit into the iron 1 ft. from end of graze. All three plates broken. *Underneath.*—Plate broken and bulged over a space of 6 in. by 6 in. at end of target, and angle iron of deck beam bulged. Outer ½ in. plate cracked through perpendicularly under graze mark. Shell deflected without exploding.
1909	"	"	Flat-headed experimental steel shell, 245 lbs., bursting charge, 5 lbs., total, 250 lbs., 18 in.	Angle of incidence, 9⅔ deg. *At upper deck, on end of deck beam.*—Struck on lower edge of target, almost on edge of centre plate. Broke hole in target 19 in. by 9 in., and cracked plate on edge through a line of rivets. Deck torn off over 2 ft. 3 in. by 1 ft. 6 in. Shell burst underneath. Deck beam broken away for about 2 ft. Plate on edge deeply indented in three places by splinters.
1883	"	"	"	Angle of incidence, 8 deg. *At breastwork deck, between deck beams.* Struck 6 in. from lower edge, 2 ft. from left. Graze mark 7 ft. 10 in. long. Iron exposed 2 ft. 3 in. from commencement of graze to within 9 in. of end of it. Bottom plate torn open for a length of 3 ft. Gape 5 in. *Underneath.*—Several pieces of plate driven through. Outside deck beam on left cracked for a length of 2 ft. horizontally, about 5 in. from bottom of beam, and bulged outwards and downwards about 3 in. Shell deflected without exploding.
1885	"	"	"	Angle of incidence, 8 deg. *At breastwork deck, on deck beam.*—Struck 18 in. from lower edge, 3 ft. 10 in. from left. Graze mark entirely across

Photographic No. of Round.	Gun and Energy of Projectile.	Charge and Brand of Powder. lbs.	PROJECTILE. — Nature, Weight, and Length.	Observed Effects.
1885 contd.				target. Iron exposed 3 ft. 4 in. from lower edge to end of graze mark. Point of shell bit into the iron at 4 ft. 10 in. from upper edge of target. Graze mark 3 ft. long. Shell then deflected without exploding. Iron plates broken through at 3 ft. 2 in. from upper edge for a length of 8 in. ½ in. plate at upper side of target cracked through perpendicularly. *Underneath.* — Deck beam cracked through 1 ft. from upper edge, and bulged. Some small splinters of wood and iron driven through deck.
1886	9 in. rifled M.L., No. 145. Striking energy 3396 foot-tons, or 121 foot-tons per inch of shot's circumference.	50 P. Pigou & Wilks, August, 1871, lot 847.	Palliser shell, 246 lbs., bursting charge, 4 lbs. 8 ozs., total, 250·5 lbs., 19·1 in.	Angle of incidence, 8 deg. *At breastwork deck, between deck beams.* Struck 5 ft. 7 in. from left, 15 in. from lower edge. Graze mark 9 ft. 6 in. long. Iron exposed for 6 ft. 7 in. Deck beam bulged underneath. Shell deflected without exploding.
1887	"	"	Palliser shell, 245 lbs., bursting charge, 4 lbs. 8 ozs., total, 249·5 lbs., 19·1 in.	Angle of incidence, 10 deg. *At breastwork deck, on deck beam.*—Struck 7 ft. 5½ in. from left, and on lower edge. Graze mark 11 ft. 3 in. long. Iron exposed for a length of 6 ft. 6 in., commencing at 2 ft. 6 in. from lower edge. Iron skin bulged, but no cracks. Deck beam, 12 in. to right of graze mark, bulged slightly.
1908	"	"	Flat-headed steel shell as before, bursting charge, 5 lbs. 4 ozs., total, 251·25 lbs., 18 in.	Angle of incidence, 9¾ deg. *At breastwork deck, between deck beams.*—Struck 5 ft. 8 in. from lower edge, 2 ft. 2 in. from centre. Iron exposed for 5 ft.; hole in it 2 ft. 7 in. by 8 in. Splinters of wood and iron driven under deck. Beam slightly more bulged. Shell deflected without exploding.
1910	10 in. rifled M.L., No. 2. Striking energy 5055 foot-tons, or 162 foot-tons per inch of shot's circumference.	70 P. Pigou & Wilks, August, 1871, lot 847.	Palliser shell, 393 lbs., bursting charge, 5 lbs. 15 ozs., total, 398·9 lbs., 26·3 in.	Angle of incidence, 8 deg. *At breastwork deck, near deck beam.*—Struck 10 in. from lower edge of breastwork deck, forming a graze 8 ft. 2 in. long. Iron laid bare for 6 ft. Broke completely through both the thicknesses of the 2nd deck plate, turning it down 1 ft., and making a rent of 3 ft. 2½ in. by 4 in. at widest part. *Underneath.* — Three rivets started near the rent, no other damage. Shell ricochetted without exploding.
1911	"	"	Palliser shell, 393 lbs., bursting charge, 6 lbs., total, 399 lbs.	Angle of incidence, 8 deg. *At upper deck, between deck beams.*—Struck 2 ft. 8 in. from lower edge, and 2 ft. 8 in. from left, grazing 9 ft. 3 in. Iron laid bare for 6 ft. Cracked 2nd deck plate through all three thicknesses,

Photographic No. of Round.	Gun and Energy of Projectile.	Charge and Brand of Powder. lbs.	PROJECTILE. Nature, Weight, and Length.	Observed Effects.
1911 contd.				bulging it down 2½ in. 3rd deck plate cracked through all three thicknesses, and bent down 5 in. Three rivets gone in vicinity of damage. *Underneath.*—Daylight through. Large pieces of plate on ground underneath, which had been driven down with considerable force. Shell burst on impact.
1912	10 in. rifled M.L., No. 2. Striking energy 5055 foot-tons, or, 162 foot-tons per inch of shot's circumference.	70 P. Pigou & Wilks, August, 1371, lot 847.	Palliser shell, 391 lbs., bursting charge, 5 lbs. 12 ozs., total, 396·75 lbs.	Angle of incidence 8 deg. *At upper deck, on deck beam.*—Struck 4 ft. from right, grazing surface, and joining 1882. Iron laid bare for 3 ft. 6 in. *Underneath.*—Deck beam bent at junction of 1st and 2nd plates, also cracked in two places. One rivet slightly started. Shell ricochetted without exploding.
1913	,,	,,	Palliser shell, 391 lbs., bursting charge, 6 lbs., total, 397 lbs.	Angle of incidence, 10 deg. *At upper deck, between deck beams.*—Struck 17 in. from right, and 21 in. from lower edge. Iron uncovered from 3 ft. from lower to upper edge. 2nd and 3rd plates bulged down 4 in. 3rd plate cracked through rivet hole for 11 in. from edge. A corresponding crack of 1 in. in 2nd plate. Five rivets gone, one started. *Underneath.*—Transverse fissure in 2nd plate, and a longitudinal one in 3rd plate. Daylight through longitudinal crack. Shell burst on impact.
1914	,,	,,	Palliser shell, 389 lbs., bursting charge, 6 lbs. 4 ozs., total, 395·25 lbs.	Angle of incidence, 10 deg. *At upper deck, on deck beam.*—Struck 8 ft. 3 in. from right, and on lower edge. Iron laid bare to within about 3 ft. of upper edge. Bulge in 1st plate 3 in. deep. Deck planking completely destroyed and broken up. One rivet started, and one out. This shot hit on a deck beam which had been struck on the end and bent back by 1909. It was shored up with skidding. After the round the skidding was much crushed, the beam bent and cracked slightly longitudinally. It was uncertain whether the shell broke up or burst.

Trial of the 35-Ton Gun against No. 33 Target, with a 4-Inch Plate in front of it for Direct Fire, and without any addition for Oblique Fire.

This being the first trial of the 35-ton gun against armour, considerable interest was attached to the occasion.

The target called No. 33, a somewhat minute description of which will be found at page 62, of Volume XX., happened to be the strongest structure standing at Shoeburyness last year, when orders were given for a trial of the armour-piercing qualities of the 12 in. 35-ton gun. But this target having been designed for the trial of lighter guns, no part of it was equal to stand a *direct* blow from a gun of this power; and as it was settled that the expense of a new target, or of a costly reconstruction, should not be incurred, the only remaining course was to place temporarily so much additional armour in front of the strongest portion of this target as would make it a fair match for a round or two from the gun fired *directly* at it. Accordingly, that end of it which in the description before-mentioned is called the "13 in. portion" was taken up for the trial. As will be seen, that part consisted of the following:—

First, armour plates, 4 ft. 6 in. wide and 8 in. thick; then 6½ in. of teak; then a broad armour plate 5 in. thick; then 6½ in. more of teak; then a skin made up of two thicknesses of ¾ in. plate, supported in rear by ribs 10 in. deep, spaced 12¾ in. apart, and resting at their top and bottom ends against the usual timber frames.

In front of this part of the target, and blocked out 5 in. from it, was placed a 4 in. armour plate, measuring on its face 8 ft. 6 in. by 7 ft. Its ends and edges were left rough as they came from the rolls, and it weighed rather more than 5 tons. As it could not be bolted to the existing armour of the target without taking off some of the plates, the new 4 in. plate was merely held up by two timber piles and struts.

Also, because any backing behind the 4 in. plate would have been useless without special means of holding it in, as it would have been easily displaced on the first entrance of the shot, it was determined to leave the plate unbacked, except where the blocking occurred.

Thus there were presented in succession to the direct fire of the gun:—a 4 in. plate, a 5 in. air space, an 8 in. plate, 6½ in. of teak, a 5 in. plate, 6½ in. of teak, and skin and ribs; or in other words 17 in. of armour in three thicknesses, 13 in. of teak in two thicknesses, and skin backed by ribs.

This disposition of armour was, of course, not by any means that which would have been recommended for a new target, but there was no choice in the matter. Also the amount of armour added will not be considered excessive when it is remembered that this portion of No. 33 target was completely penetrated (Round 1843) by a shot from a 25-ton gun, fired with a reduced charge of 75 lbs. of pebble powder, at 200 yards. (See page 69, Vol. XX.)

The trial of the gun with *oblique* fire was made against the "13 in. portion" of No. 33 target, without any alteration being made to it.

The first experiment, that with *direct* fire, took place on the 20th June, 1872. The gun was placed opposite the target at 70 yards distance.

The first round (No. 1890) was fired with a Palliser large cored shot, 1·5 diameter head, 31·5 in. long, 11·91 in. diameter, weighing 685 lbs., with a bursting charge of 9 lbs., and a charge in the gun of 110 lbs. of pebble powder.

The shell struck fair in the central part of the 4 in. plate, 3 ft. 2 in. from the right timber pile, and 3 ft. 4 in. from the top of the plate, burying itself in the target.

The striking velocity of the projectile was about 1295 ft. per second. Its energy on impact about 8090 foot-tons, or 215 foot-tons per inch of its circumference. The hole in the 4 in. plate measured in front 12·1 in. by 12·5 in.

It has not been possible yet to ascertain the exact depth to which the point of the projectile reached, but after careful examination, it is supposed that it did not quite touch the skin of the target.

If this be the case, the hole in the 5 in. armour plate would require considerable enlargement before the full diameter of the shot could be passed through it, and therefore the work done on the target was some way short of complete perforation. This is borne out by the effects produced on the rear of the target, where the injury was confined to the skin being very slightly bulged, three ribs very slightly curved, one rib (the 7th from the end of the target) being split, and several rivets stripped.

Altogether the effect was somewhat less than was generally expected.

As this part of the target had thus proved itself to be fully a match for the gun, the next round (No. 1891) was aimed *directly* at a weaker part, a point immediately in front of the joint in the 8 in. armour being selected for the purpose.

The projectile, charge, and range were the same as in Round 1890, but the shell was this time filled with sand only. Total weight, 699 lbs. The velocity and energy were much the same as before.

The point struck was 2 ft. 8 in. from the right edge of the 4 in. plate, 1 ft. 10 in. from its upper edge, and 8 ft. 6 in. from the left end of the target.

The 4 in. plate had not been adjusted after the last round, but was left with its upper edge resting nearly against the face of the target. The 4 in. plate at the point struck was thus about 3 in. from the face of the 8 in. armour of the target.

The projectile passed through the 4 in. plate, making a hole 12·2 in. by 12·6 in., and into the target with the upper side of its body on the very joint of the 8 in. armour.

Its head passed through the target, breaking off about 3½ in. beyond the front stud, and dividing into several pieces, one of which went about 30 yards to the rear.

The body of the projectile remained in the target, protruding through the skin between the 9th and 10th ribs, which were thrust apart by it. The hole in the skin was irregular, and measured about 12 in. by 15 in. The 7th, 8th, and 9th ribs were bulged, and the 10th and 11th bulged and broken. The rivets in the 10th and 11th ribs were carried away, and other rivets were stripped. The whole target, with its timber frames in rear, appeared to have been driven back by the blow, but it recovered its position.

After this trial, the 4 in. plate was taken away altogether, and the gun moved into such a position that at 70 yards distance it could be laid at an angle of 60 deg. with the face of the target.

A shell, or rather a large cored shot, the same as before, filled with sand, was fired with 110 lbs. of pebble powder in this *oblique* direction at the upper 8 in. plate of the "13 in. portion" of the target.

This experiment took place on 18th July, 1872. The number of the round fired was 1915.

The shot struck the plate 5 ft. from the left end of the target, and 2 ft. 6 in. from the top.

The hole formed in the front plate measured 16 in. horizontally, and 15 in. vertically. The outside horizontal dimension, measuring the scoop on the face of the plate, was 22 in. The plate was slightly buckled by the blow.

The projectile passed through the 8 in. plate at an angle of about 27 deg. from the perpendicular, and, inclining very slightly downwards, its point entered the 5 in. plate to a depth of about $3\frac{1}{2}$ in., the diameter of the indent thus formed being 6 in.

The 5 in. plate appeared to be dished about 2 in.

The point of the projectile remained in the indent in the 5 in. plate, filling it flush with the surface. The rest of the shell broke up in small pieces.

In rear, about 10 rivet heads were broken off, two ribs were very slightly bent, and one slightly cracked in the rear flange. The whole end of the target, with its timber support, was driven back about $2\frac{1}{2}$ in., but it sprang forward again about 2 in.

The general conclusions to be drawn from this trial are that a well designed structure presenting 17 in. of armour, disposed in three thicknesses, with timber between them, and supported by a skin $1\frac{1}{2}$ in. thick, and ribs of suitable construction, would resist a Palliser projectile fired *direct* from the 35-ton gun at the closest range, even at its weaker points. Also, that a similar structure presenting 13 in. of armour, in two thicknesses, with timber, skin, and ribs, as before, will resist at any point the same projectile when striking with an angle of incidence of 60 deg.

Trial of the Turret of H.M.S. "Glatton."

As the turret has now become a prominent feature in all the more important projects for Coast Defence, a short account of the experiment which took place at Portland on the 5th July, 1872, will not be out of place in this Paper.

In some respects a ship's turret has to fulfil conditions which need not be taken into account in designing one for Coast Batteries, but in the main, of course the requirements are similar, and the same general principles of construction should be embodied in both.

The "Glatton" trial was therefore looked forward to with much interest by those who have to do with the construction of land turrets, more especially as our experience in this country of the behaviour of turrets under fire is very limited.

The only other occasions on which actual turrets have been tried in England are (1st) the trial of the cupola of the "Trusty," in 1861, briefly described at page 200, Vol. XI.; (2nd) the trial of one of the turrets of the "Royal Sovereign," in 1866.

With regard to the former, so complete has been the revolution in the power of artillery in the last 12 years, that the experience gained in that trial is almost valueless for present purposes; and with regard to the latter, as the guns of the Bellerophon used on the occasion were only 9 in. $12\frac{1}{2}$-ton guns, and the armour of the turret only 10 in. at the gun port and $5\frac{1}{2}$ in. elsewhere, the data then obtained may also be considered almost obsolete.

Besides these two trials of actual turrets, there was the experiment upon targets representing turret sides at Shoeburyness, in 1871, described in Paper X., Vol. XX. This last-named experiment did not, of course, solve any question connected with the working parts of a revolving turret, but it did give some very conclusive results as to the resistance of the armour plating of turrets.

Before leaving the subject of these previous trials, it may be well to notice briefly that of the "Royal Sovereign."

Three rounds took effect on that occasion. They were all fired with ogival-headed steel shot of about 250 lbs. weight, with 43 lbs. R.L.G. powder, at 200 yards range.

One struck close to the port on the 10 in. armour ($5\frac{1}{2}$ in. + $4\frac{1}{2}$ in. plates), and, breaking away a piece of the outer plate, it glanced into the turret. A good deal of the effect of the round upon the wall of the turret was therefore lost.

The next was against the part protected by only $5\frac{1}{2}$ in. of armour. It struck on the joint of two plates, and turning upwards, lodged itself in the wooden backing. Many of the armour bolts gave way.

Both of these shot were aimed direct at the centre of the turret, and both struck near the bull's-eyes. Therefore, there was no great strain put upon the revolving machinery of the turret, and it sustained no injury.

The third and last round was aimed low, and struck the deck at a distance of about 6 ft. from the turret, where there was 6 in. of planking on 1 in. plate and deck beams. This shot glided along the deck, scoring it to a depth of about 3 in., and glanced off the glacis plate against the $5\frac{1}{2}$ in. armour of the turret, on which it caused an indentation 17 in. long, 9 in. wide, and $3\frac{1}{2}$ in. deep, taking extreme measurements. The shot then went away, and fell into the sea at a distance of about half a mile. This shot was not aimed directly at the centre of the turret. The turret turned freely by hand after this blow also.

Two points may be noticed in this trial:

1st. That the turning machinery of the turret was very slightly strained in the first two rounds, and that it had to bear only a small share of the work in the shot in the last round.

2nd. That the trial afforded no experience as to the effect of a shot impinging upon a deck near a turret, at such an angle as would allow of its head displacing or penetrating the glacis.

But, to proceed with the "Glatton" trial. The turret of this ship is about 30 ft. 6 in. in external diameter, 23 ft. 9 in. in the clear internally, and it carries two 25-ton guns.

On the side in which the ports are cut, the armour is 14 in. thick, backed by 17 in. of teak, and a skin composed of two thicknesses of $\frac{5}{8}$ in. plate, supported by vertical ribs, 10 in. deep. There is also an inner lining of $\frac{1}{4}$ in. plate attached by tap screws to the rear flanges of the vertical ribs. The rest of the turret is covered with 12 in. plates, backed by 19 in. of teak, with skin and ribs as in the port side.

The armour is in one solid thickness, and the plates, 3 ft. $7\frac{1}{2}$ in. wide, run horizontally, with a joint all round, half way up the turret.

The armour bolts are $4\frac{1}{2}$ in. in diameter, and they have conical heads and plain hexagonal nuts.

Thus, it will be seen that the front or strong side is almost exactly represented by No. 34 target, the trial of which is described in Paper X, of last year's volume.

The two guns remained in the turret during the trial, but to prevent unnecessary injury to them from without, the ports were blocked up with masses of timber.

The gun used for the experiment was the 12 in. 25-ton gun of H.M.S. "Hotspur," which was moored at 200 yards from the "Glatton."

The projectiles fired at the turret were Palliser cored shot, 11·92 in. diameter, 1·5 diameter head, weighing 600 lbs., fired with charges of 85 lbs. pebble powder, giving a striking velocity of about 1273 ft. per second. The energy in the shot on impact was therefore about 6750 foot-tons, or 181 foot-tons per inch of shot's girth.

A goat, a rabbit, and a fowl, were shut up in the turret for the trial.

The two ships were placed inside the breakwater. The day was perfectly calm and the sea like glass.

Two trial rounds with 67 lbs., and two with 85 lbs. charges, were fired in the first instance at a canvas screen on board the "Glatton." These struck from 1 ft. to 2 ft. 6 in. low, and from 1 ft. to 1 ft. 6 in. to the left.

The first round fired at the turret missed it altogether, merely injuring the stanchions on its roof. It may be worth recording that the mere running forward of the "Hotspur's" 25-ton gun, mounted on a large central turntable, caused the ship to list over about 4 deg., and after the gun was fired with a battering charge, she rolled for about 10 min.

The first shot that took effect upon the turret, struck the upper 14 in. plate just above its lower edge, and at a point 4 ft. 9 in. from the proper right of the right port. Just below the shot-mark, the 12 in. plating ended.

The shot struck partly on a bolt, a length of about 10 in. of which was cut off and thrown to the front. The upper armour plate was lifted about 2 in. at its end, and $\frac{5}{8}$ in. at the part struck. The 12 in. plate below it was forced downwards about $\frac{1}{2}$ in., injuring for a length of about 10 ft. the shelf-piece upon which it rested. The vertical joints of the armour were also slightly opened.

The shot buried itself in the turret, the base end breaking off. The point penetrated to a depth of 2 ft. 3 in. The distance from the face of the armour to the top of the core of the shot was 16 in. The moulds of the armour plates were opened in the shot hole, and the plate was separated into two halves along the top and bottom edges.

Inside the turret, the following were the effects of this round:—

The nut end of the armour bolt which the shot had struck was broken off, and was found lodged on the trunnion of one of the guns. The washer of the same bolt was found on the gun slide.

Two widths of the inner lining ($\frac{1}{4}$ in.) of the turret were stripped off for a distance of about 6 ft. from the roof, and bent back 4 ft. 6 in., exposing to view the inner ends of three armour bolts. This lining came against the overhead shot run, and would have interfered with its use in action for some time. This extensive injury to the inner lining was principally due to the driving in of the end of the armour bolt.

The skin was bulged about 7 in., and torn open immediately over the point of the shot, where a joint occurred in the front thickness of the skin. Some wood backing protruded through the rupture in the skin.

One rib was broken through, another bent and cracked, and another bent.

A knee of a roof beam was broken back.

Nearly 100 of the tap screws securing the inner lining to the ribs were broken, or otherwise damaged.

On the outside of the roof of the turret, 23 tap screws securing the roof plates to the armour were sheared off.

The animals in the turret appeared to be unharmed, but it must not be inferred from this fact that there would have been no casualties amongst the crew of the turret. The turret revolved well either by hand gear or steam after this round.

The second shot that took effect was aimed at a bull's-eye on the lower 14 in. armour plate, midway between the ports of the turret, but it struck lower than was intended, and, slightly grazing the glacis plate, it entered the armour immediately above the deck.

The graze in the glacis was $1\frac{1}{2}$ in. deep. The head of the shot remained in the hole in the armour, but it recoiled an inch or two, and when taken out the extreme depth to which the point had reached was found to be 13·5 in. The base of the shot broke up and fell outwards. The flap or flange attached to the turret for the purpose of closing the interval between the armour of the turret and the glacis was cut away and turned up, but the injury did not interfere with the revolution of the turret. It worked freely both by hand and steam power after this round.

Inside the turret there was no damage done beyond the displacement of two buffers on the front of one of the gun slides, which were merely shaken out of place. The animals were uninjured, and in all probability there would have been no casualties amongst the crew. Below deck the shelf-piece on which the armour rested was found to be a little damaged, after this round, in much the same way as in the former round. The deck beams and plating, viewed from underneath, did not shew signs of injury.

After these two rounds the port stoppers were removed, and the guns in the turret were run out and fired. All was found to be in working order.

The trial was thus concluded.

The programme for the day originally included three rounds—one at the 14 in. armour at one side of the ports, another between the ports, and the third on the glacis—but the second hit was assumed to have answered the purpose of both the second and third rounds as intended, and therefore the experiment was cut short.

On the whole it may be said that the trial did little more than confirm the results obtained with No. 34 target at Shoeburyness, in 1871, as reported in Paper X. of last year's volume. For both of the shots hit exactly in a line directed upon the centre of the turret, and therefore the effect upon the turning gear was comparatively slight. Also as regards the effect of a heavy blow from a plunging shot on the glacis, close to the turret, nothing was learnt from the trial, and yet this is a matter of the greatest importance.

It is worth observing, with reference to the second round against the turret, that in the trial of No. 35 turret target, in 1871 (see Paper X., Vol. XX.), a shell—Round No. 1795—which struck close to the bottom of the target turned in the direction in which it felt least resistance, and passed vertically downwards into the earth. It is probable that a similar result, which would threaten fatal injury to a turret, was just avoided in the present trial by the graze on the glacis giving the shot such direction as disinclined it to turn downwards on entering the armour.

To have made the experiment at all complete, the turret ought to have received a shot directed at a point on its side some few feet away from the centre, as viewed from the gun. Also the ship should have been heeled over until its deck was inclined at some moderate angle to represent the position it might assume with reference to the guns of another ship in action at sea, or with reference to the guns of a land battery, and then a heavy blow should have been planted on the glacis, and another quite low down on the turret's side.

Until these points have been more thoroughly tried, it cannot be said that our information on the subject of either land or ship's turrets is as complete as it ought to be.

Before closing the account, attention should be directed to the unsuitableness of iron as a material for the innermost lining of a structure which is liable to be severely strained by cannon shot.

In the first round of this trial the crew of the turret would have received a great number of injuries from the splinters of the $\frac{1}{4}$ in. inner lining plates and their fastenings, and besides this the damaged part of the lining would have impeded the working and loading of one of the guns for some little time.

It is considered, therefore, an essential condition that a soft material should be used for lining structures of this kind, and nothing has yet been discovered that will answer the purpose so well as a strong closely-worked rope mantlet.

In itself rope is harmless as regards the giving off of splinters, whilst it is very effectual in stopping them; it deadens noise and vibration arising from blows received on the armour, and when once soaked in a saturated solution of chloride of calcium, as recently used on the recommendation of the Chemist to the War Department, it becomes perfectly incombustible. In addition to these qualities there is also the advantage that in case of very extensive injuries, rope-work is less likely to interfere with the working of the gun, and would in all probability be more easily removed, than a lining of almost any other material.

Penetrative Power of Projectiles Fired under Water.

Questions having arisen as to the vulnerability of armour clad ships when attacked by projectiles aimed at parts below the water-line and under the armour, it was proposed that a target representing an unarmoured part of a ship's side should be constructed to test the offensive powers of such projectiles under water. But before proceeding to this length, it was deemed expedient to make some preliminary experiments to ascertain whether such a trial would be likely to give any useful results.

Accordingly, some 2 in. wooden targets were placed vertically on the sands at Shoeburyness, at a distance of 38 yards from the muzzle of a 9 in. 12-ton gun which was mounted on the end of the pier. The targets stood in from 5 ft to 8 ft. of water during the trials.

At first, Palliser service shot were used, with battering charges. When fired at a depression of 8½ deg. these shot ricochetted from the very surface of the water. At depressions between 10 deg. and 12 deg., the same shot did not rise; and when the tide went out, they were found lying on the sand, at about 48 yards from the gun.

The three shot that were thus found, were from 5 to 7 yards to the right of the line of range, and all had their heads turned to the left half front.

After this, some flat-headed cast-iron shot of the same weight were fired, with battering charges. These shot ricochetted at 7½ deg. depression, but did not rise when fired at 8½ deg. depression. Those that remained under water were found lying on the sand at from 45 to 66 yards from the gun.

One of these shot was 3 yards to the right of the line of range, and had its head turned square to the left; another was 3 yards to the left, and had its head straight to the front; another was in the line of range, and had its head straight to the front; the fourth was 2 ft. to the left of the line of range, and had its head turned to the left half front. This last was the shot which had gone only 45 yards from the gun. The wooden targets had been removed before these rounds were fired.

These trials took place in the winter of 1871-2, and the results being so conclusive, it was thought to be quite unnecessary to make any further experiments in that direction.

EFFECT OF COMMON SHELL USED AGAINST UNARMOURED SHIPS.

This experiment was made for the purpose of obtaining some information for the Admiralty as to the destructive effects produced by common shell on unarmoured wooden and iron frigates, relatively.

For the purpose of the trial, two large targets were set up at Shoeburyness, the one representing the side of an iron and the other the side of a wooden frigate.

The outside plating of the iron section was ½ in. thick, fastened with ¾ in. rivets, on ribs or frames 10 in. deep, made of angle irons, 10 in. by 3½ in. by ½ in., with single angle irons on the front side, 3 in. by 3½ in. by ½ in, riveted with ¾ in. rivets. On the back of the ribs was an inside lining of teak, 2 in. thick, with iron tongues in all the joints, secured to the ribs with ⅜ in. galvanized screw bolts and nuts.

The target was provided with short lengths of main and upper deck beams of the construction used in frigates of the class represented, covered with 4 in. oak.

The outside planking of the wooden section was of English oak, from 4 in. to 7 in. thick, on timbers tapering from 12 in. to 9 in. in thickness, with an inner lining of 5 in. of teak, strongly braced and bolted together, and secured with massive fastenings, as in vessels of the class represented. This target also had portions of the upper and main decks.

The guns used were the 7 in. rifled muzzle-loading gun, of 6½ tons, and the 64-pr. rifled muzzle-loading gun, of 64 cwt. They were placed at 70 yards from the targets.

The trials took place in June, 1872.

The common shells from the 7 in. gun carried bursting charges weighing from 8¼ lbs. to 10 lbs. The shells weighed from 104 lbs. to 117 lbs., and were fuzed with Pettman G.S. fuzes. They were fired with 10 lbs. and 14 lbs. charges in the gun, the former giving velocities of about 1080 ft., the latter from 1215 ft. to 1250 ft. per second. Some were filled with sand and fired blind.

The 64-pr. shells carried bursting charges of from 6 lbs. to 8 lbs., and were fuzed as the others. They were fired with 5 lbs. and 8 lbs. charges, giving velocities varying from 1030 ft. to 1230 ft. per second. Some of these also were filled with sand.

Three rows of wooden targets were placed in rear, in order to observe the distances at which the shells burst, and the lateral effects of the explosions.

It was almost impossible to lay down any general rule, from the trial, as to the breaking up or explosion of the shells, on account of the vast variety of resistances offered by different parts of the structures.

The committee reported that "if the shell hit on a knee, a rib, or a diagonal iron brace, it almost invariably broke up or exploded in passing through the ship's side; if, on the other hand, it passed fair between two ribs in a place where the resistance was confined to the wood planking or iron plating, it usually did not break up or explode until it had passed from 6 ft. to 10 ft. from the side."

Some of the shells broke up in passing through the ship's side without bursting, the bursting charge in several instances being simply fired in the onward flight of the shell to the rear.

In every case of a shell exploding in, or soon after passing through the side, the effect between decks was terribly severe, and the greatest effect was noticed when the shell struck on the stronger parts of the sides.

It is difficult to say which ship suffered least, or what were the comparative effects between decks.

The timber ship's side had so much iron in its composition, in the shape of massive knees, bolts and diagonal braces, that it was almost impossible to pass a shell through timber without meeting with iron also, and this led in many rounds to the timber ship giving off more destructive splinters than the iron-side. On the other hand, it was thought that the kind of injury done to the iron-side would be more likely to lead to the sinking of a ship than that done to the timber-side.

The experiments showed in a very marked way the disadvantage of using iron in any shape in the lining of defensive structures, as the iron tongues in the joints of the inner teak planking of the iron ship's side, proved extremely inconvenient when the lining was ripped off.

It is important to add that, subsequent to the above trials, some rounds were fired at the iron ship's target from the 10 in. 18-ton gun, with blind common shells, that all the shells broke upon the target, and that, judging from the utter destruction of a number of targets placed in rear, the effect between the decks of an unarmoured ship from the fire of such guns would be terrific.

Prussian Trials in 1872.

A short notice of some interesting trials of German guns against armour-plated targets, which took place at Tegel, in August, 1872, will conclude this paper.

The guns used were :—1st, the 28 centimetre breech-loading gun, of 27 tons 1 cwt., calibre equal to 11·024 in. This threw Grüson's chilled shells of 515·9 lbs., with charges of 88·18 lbs. of Government prismatic powder, giving a muzzle velocity of 1394 ft. per second, the energy of the projectile at the muzzle being 6953 foot-tons. 2nd, the 26 centimetre breech-loading gun of 21 tons 13 cwt., calibre equal to 10·236 in. throwing similar shells of 414·5 lbs., with charges of 70·55 lbs. of prismatic powder, velocity and energy of the projectile at the muzzle being 1385 ft. per second and 5514 foot-tons respectively.

The weights and measures given in this account are all English.

One target was composed of 12 in. armour plates, made at Sheffield, backed by two layers of 9 in. oak, and a skin of $\frac{5}{8}$ in. iron plate. The other of 10 in. plates, similarly backed.

The guns were placed at 164 yards from the targets. The shells were filled with dried peas.

Commencing with the heavier gun, the results were as follows :—

A shell fired with full charge, and striking with 1370 ft. velocity, completely penetrated the 12 in. target, and one fired with a reduced charge of 77 lbs., easily penetrated the 10 in. target.

From these results, the committee conducting the trials inferred that this gun would have passed through a target made of 12½ in. or even 13 in. plates at this range, or that it would penetrate the 12 in. target at 437 yards range; also, that with a full charge, it would penetrate the 10 in. target at 1400 yards, or an 11 in. target of similar construction, at 1000 or 1100 yards.

With regard to the 26 centimetre gun, its shell, fired with full charge, completely penetrated the 10 in. target with 1338 ft. velocity, but once it failed to do so with a velocity of 1371 ft. This, however, was apparently due to the inferior quality of that particular shell.

With a charge, rather above the regulated full charge, namely, 72·75 lbs., a shell striking the 12 in. target with a velocity of 1376 feet, entered to a depth of 30 in.

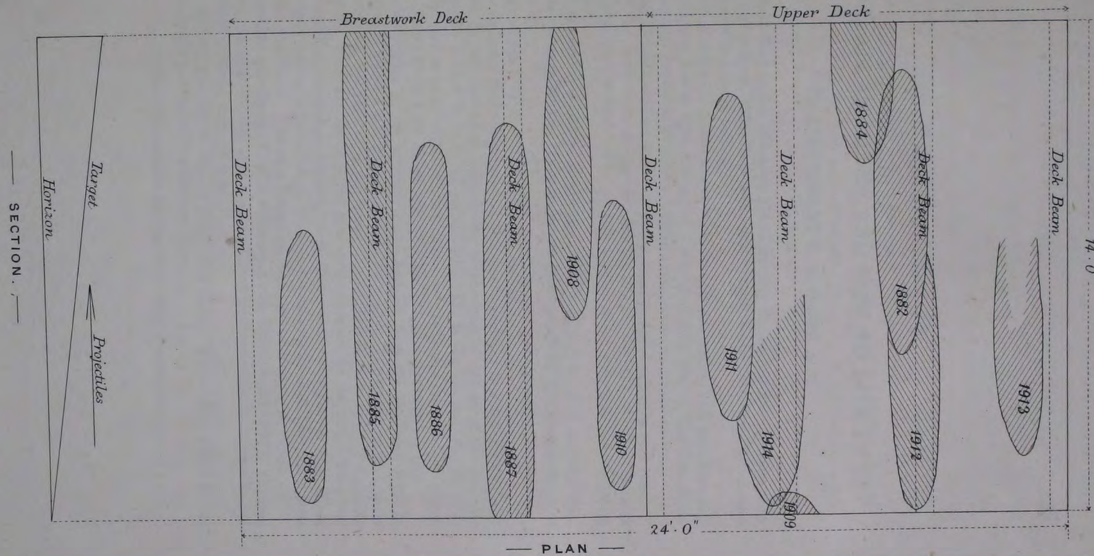
From this round the committee reasoned that the shell would have penetrated the target had the armour plates been 11 in. instead of 12 in. thick; and they also considered that the shell from this gun would completely penetrate a 10 in. target similarly constructed, at 490 yards.

It is not easy to compare these results exactly with those which have been obtained with the corresponding guns in our service, because the construction of the German targets appears to have been different from our usual construction as regards thickness of skin and other particulars; but on the whole, it is thought that our 11 in. 25-ton and 10 in. 18-ton muzzle-loading guns would have compared very favourably with the German guns on this occasion.

T. I.

SHIPS' DECK TARGET.

DIAGRAM SHEWING SHOT-MARKS OF ROUNDS IN TABLE I.



Kell, Broˢ Lithʳˢ London.

Pl. XXI.

PAPER XVII.

FOUL AIR IN MINES, AND HOW TO LIVE IN IT.*

BY LIEUTENANT J. E. GIBBS, R.E.

When on duty at the Defensive Mines one day during the Mining Operations of July and August, 1871, three men were brought out in a fainting state, caused by a rush of foul air in untamping.

Thinking that some means might be devised for preventing such accidents, and the consequent loss of time and panic, I consulted with Major Malcolm, R.E., who proposed Professor Tyndall's firemen's respirator for consideration.

Colonel Lennox sent me to the maker to enquire, and I returned with one.

With the assistance of Quarter Master Sergt. Ingram, of the Chemical Laboratory, and several books of reference, I have collected the following notes:—

After exploding a charge of gunpowder at a gallery-head, it becomes dangerous to untamp, because of the poisonous gases produced by the combustion of the powder.

The gases are CO_2, N, CO, HS, C_2 H_4, and H.

The only gases that are present in sufficient quantities to harm are CO_2 and CO; CO_2 to the amount of $\frac{1}{200}$th (·005) of the bulk of the air at the gallery-head would render it unfit to sustain life. CO to the amount of $\frac{1}{100}$th (·01) would do the same; 100lbs. of powder evolve 22559·38 cubic inches of gas at 60 deg. F and 30 in. B, of which 9429.7896 are CO_2 and 2249·848 are CO.

Miners working in the presence of the foul air from the explosion suffer in two ways; if affected suddenly, they feel a burning at the nape of the neck, their limbs tremble, and they turn giddy and faint. This is to be attributed chiefly to the CO. They are also affected in a slower manner by the CO_2. They feel their breathing becoming difficult, as if there were a weight on their chest, with a tight feeling in the head; if not brought into the fresh air they are in time overcome and faint. This also brings on headache on coming into fresh air.

The specific gravity of CO with reference to the atmosphere is 0·967; the gas, therefore, floats at the top of the gallery, about the level of the men's heads, and consequently affects them at once.

The specific gravity of CO_2 is 1·529 that of air, it therefore sinks to the ground, and is slower in its action on the men.

* This Paper originally appeared in *The Royal Engineer Journal.*

Any method of getting rid of the foul gases by chemical means must interfere greatly with the progress of the work.

In any case there would be considerable difficulty in destroying the CO, as it has neither acid nor basic properties. A *good* system of ventilation through hose would clear the galleries of the foul air, but would not overcome the difficulty of untamping, because at any moment of the process there may be a rush of foul gas, which would take effect on the men at work before the ventilation could carry it away.

A good respirator worn by each of the men employed at untamping might overcome this difficulty.

Professor Tyndall's respirator for firemen is constructed with a view to enable the men to inhale pure air when at work in a burning house, by separating the smoke and noxious vapours.

It consists of two parts:—

1st—The Mouthpiece.

2nd—The body of the respirator.

The mouthpiece is an invention of a Mr. Carrick, Hotel-keeper at Glasgow, who has patented it. This has two valves, '*i*' and '*e*,' (see *Nature*, June 15th, 1871).

The air inhaled comes from below, up through the body of the respirator and through *i*. The exhaled breath closes *i*, and escapes through *e*, thus keeping the contents of the body of the respirator cool.

There is an aperture O, which fits closely round the lips, and to prevent respiration through the nose, there is a nose pad fixed on the top of the mouthpiece.

A wire gauze partition separates the mouthpiece from the contents of the body of the respirator.

The body of the respirator is about four or five inches long, and contains, at the top, a layer of cotton wool soaked in glycerine to prevent any solid particles escaping into the mouth from the lower layers, and also to stop those very minute particles of the smoke that may not have been arrested below. Next comes a layer of dry cotton wool, then a layer of charcoal fragments, another layer of dry cotton wool, and then some fragments of slaked lime. Below this come some more cotton wool and then the wire gauze cover or cap at the bottom.

For smoke the layer of lime is not necessary, but in mines it would be of the greatest use, because it has a great attraction for CO_2.

The layer of charcoal would absorb the CO and the HS in the air, and the mixture inhaled would be perfectly innocuous.

The disadvantages of this respirator in its present form for mining purposes are:—that it is too long, and an effort is required in breathing through the small valves.

Mr. Ladd, of Beak Street, Regent Street, the maker of these respirators, has made some improvements in the mouthpiece, which may overcome some of the inconveniences of the old pattern.

I received permission to use the Royal Engineer workshops for experimenting on the shape best suited for use in the mines. Tyndall's respirator has been severely tested in dense and pungent smoke from resinous pinewood, and succeeded to the perfect satisfaction of Captain Shaw, of the London Fire Brigade. Firemen are to wear it attached to hide helmets, but for the mines any arrangement, which will support the respirator and keep it close to the mouth during work, without being hot or uncomfortable, will suffice.

EXPERIMENTS MADE WITH THE RESPIRATOR.

On Saturday, August 19th, 1871, a trial of the respirator was made in the Chemical Laboratory, S.M.E., in the presence of Colonel Lennox, Dr. Fox, and others. I was shut up in an air-tight cupboard, with the respirator on. By my side were jars containing CO and CO_2 to a proportion of $\frac{1}{200}$th each of the cubic content of the cupboard (141,698·4 cubic inches) not allowing for the space occupied by my own body and the stool on which I sat.

The respirator contained animal charcoal and lumps of slaked lime mixed together, thus dispensing with one layer of cotton wool. After emptying all the jars I remained for ten minutes in the full mixture (fifteen minutes in all) without the slightest discomfort except from the awkward shape of the respirator. I was then called out.

On Monday the 21st, another trial was made in the presence of Dr. Fox and Lieutenants Abney and Galwey. This time a rabbit and three birds were placed in the cupboard with me. The respirator contained in addition to the charcoal and slaked lime a small quantity of sulphate of soda. The only cotton wool used was a small layer soaked in glycerine at the top, and a thin layer of dry wool at the bottom. The sulphate of soda was introduced according to Professor Graham's advice, in order to give an atom of O to the CO to form CO_2, becoming itself sulphite of soda.

The content of the cupboard was 141,698·4 cubic inches; from this would have to be deducted the space taken up by my body, say $3\frac{1}{2}$ cubic feet (Dr. Parkes' Hygiene). or roughly 6,000 cubic inches, leaving 135,698 cubic inches.

1,890 cubic inches of CO_2 in jars were introduced, and 921 cubic inches of CO in jars. After all this had been emptied out, 1,000 cubic inches more of CO were introduced from a pressure bag, making altogether—

1890 cubic inches of CO_2
1921 cubic inches of CO

or 3,811 cubic inches of poisonous gases in addition to my exhaled breath, or about 3 per cent. of the capacity of the cupboard. In order to perfect the diffusion of the gases, I waved a towel about constantly, and after the end of the trial the fact of a taper being extinguished at the top of the cupboard showed that the CO_2 had been stirred up to the top.

The rabbit and two birds died at the same time, about 23 minutes after the cupboard was closed, while the CO from the pressure bag was being introduced. I stayed in the cupboard 30 minutes (five minutes after the mixture was completed, and seven minutes after the death of the animals). When I came out I felt a pressure on my ears, as when descending too rapidly in diving; Dr. Fox said that this was produced by my blood, my heart then beating at a *high rate.*

This was satisfactory, as showing that the gases had not affected me, but only the exertion of breathing through the respirator, for 30 minutes, combined with the heat of the close atmosphere in which I was.

To prove that the gases did not affect me, I quote some extracts from Dr. Parkes' Hygiene. "Dr. Angus Smith says that breathing CO_2 to the extent of 1·5 to 2 per cent. produces *slowness of heart action*, while the respirations become quickened, if not gasping; this is perceptible with as little as ·1 per cent." —"Less than ½ per cent. of CO has produced poisonous symptoms, and more than 1 per cent. is rapidly fatal to animals. CO in excess produces loss of consciousness, *s'owness of heart action*, and finally paralysis of the heart."

The slowness of diffusion of the two gases was remarkably shown by the fate of the third bird. The cage which held it was suspended at the top of the cupboard. The bottom, back, and top were of wood, the other sides were of wood for about 1½ in and then of wire. The bird, which was at first on a perch, was very soon affected by the impure air, and fell to the bottom of the cage. Here the wooden bottom and sides evidently contained a layer of pure air, for although the bird had lost consciousness, and indeed was considered to be dead, yet after being brought out into fresh air it was revived by ammonia, and after an hour or so fluttered away. The other animals, that were not so protected, died before all the gases had been introduced.

On examining the sulphate of soda, very little was found to have been changed into the sulphite; it would therefore seem that a constant change occurred, the sulphate giving up oxygen to the CO, becoming sulphite, and then the sulphite taking oxygen from the air to form the sulphate. Whether the good effect of the first change compensates for the loss of free oxygen in the second change, is a question for the opinion of a chemist; however, Professor Graham's recommendation is of great weight.

All that were present agreed that the trial was perfectly satisfactory, and I think this is a fair conclusion. For the object in view throughout has been to devise some plan by which a man may work for some time in a foul mine, and may be secure from the effects of a rush of foul gas caused in untamping, &c.

Defensive mines, though small, poison the ground more effectually than overcharged mines, which allow most of the gas to escape. I have before shown the total amount of CO and CO_2 evolved by the explosion of 100 lbs. of powder, which according to our late operations seems to be an average charge. It is probable that a large proportion of these gases would escape into the air, and that the rest would be diffused equally all round the charge. Therefore, only a small amount is likely to be encountered at any one point.

Hence it would seem that the respirator, which has succeeded with very powerful mixtures of poisoned air, would be quite enough to guard the miners from any of the gases from explosions.

It only remains now to hit upon a convenient shape, which will not render the breathing laborious, and during the last few weeks I have been engaged in superintending the making of a model of what seems to be a convenient shape for a mining respirator on Professor Tyndall's principle, and with which it is proposed to make further experiments.

Mr. Ladd, of Beak Street, kindly lent me a mouthpiece that he had devised, to be fitted into a hide helmet for firemen. This was very different from the original Carrick form. It was made of soft metal, large enough to include the nose and mouth, and it fitted close to the face by means of an india-rubber tube filled with water, running as a pad round the inside edge of the mouthpiece. In the bottom of the mouthpiece was a short tube, containing the inlet valve, and intended to be connected in some manner with the box containing the chemicals. In the front of the mouthpiece, on a level with the mouth, was another short tube containing the outlet valve. The valves were very simple; a ring of hard wood, of about ½ in. interior diameter, fitted closely into the tube by means of cotton packing. On one side of the ring was a flap of india-rubber fixed to it at one point by a soft metal clip on which it hinged. This was so light that ordinary breathing set it at work without the slightest difficulty.

Mr. Ladd told me that he had not been able to make up his mind as to the best way of connecting the mouthpiece with the box containing the chemicals. It occurred to me that, as it was desirable to have the whole respirator as small as possible, it would be convenient to turn the box part up the front of the mouthpiece, reversing the valves as fixed in Mr. Ladd's mouthpiece.

The diagrams on Pl. XXII. show, without necessity for much explanation, the different parts of the respirator. It is made of pewter, with the exception of the two tubes containing the valves, which are of zinc. To economize space, I have made the box to fit immediately on the front of the mouthpiece, and to abut against the side of the inhaling tube, which is consequently closed at the end and perforated on the side next to the box. For the same reason I have shortened the mouthpiece considerably, so that it comes only just below the under lip, instead of below the chin, as in Mr. Ladd's. This latter difference would, of course, be of greater advantage to the miner, who generally throws off as much clothing as possible, than to the fireman, who is obliged to wear a large helmet.

It is necessary that the opening at the top of the box should be sufficiently large to allow the cotton wool and the chemicals to be pushed well home with the finger, especially the lowest layer of wool, which should fit into the corners of the box at its junction with the tube. There should be a cap or lid to the box, perforated so as to admit the air freely.

The respirator should be kept in a convenient place near the mines when likely to be required, together with the chemicals in stoppered bottles. When wanted for use, a thin layer of cotton wool steeped in glycerine should be carefully packed round the tube at the bottom of the box. Then two-thirds of the box should be filled with animal charcoal and lumps of slaked lime, mixed together. Above this should be a layer of sulphate of soda, covered by a thin layer of dry cotton wool. The proposed method of fixing the respirator to the face is by light straps on a similar principle to that of the ordinary dog muzzle.

The india-rubber pad will enable it to fit closely and comfortably to the face, while in the case of a man with an exceptionably broad or narrow face, the softness of the metal will allow of its being pinched to the required shape.

I believe that this respirator will be found to be of great service in military mining, by enabling men to perform in perfect safety the dangerous work of untamping immediately after an explosion, and to advance through any soil, however much it may have been poisoned by gun-powder, gun-cotton, or stink-pots.

But besides its military uses, I believe that a similar respirator would be of the greatest service in many civil operations; for instance, in exploring a colliery to recover bodies after one of those awful catastrophes which are of such frequent occurrence. A man, who would otherwise be driven back by the foul gases, might, by wearing an efficient respirator, defy the poisoned air, and be the means of restoring to life many of the victims of the explosion. In such a case as this, special chemicals might be required to meet the particular gases in the galleries, but slaked lime would no doubt overcome the effects of the carbonic acid of the "after damp."

There is another advantage in the present form of mouthpiece over the old one, besides the comfort in breathing and fit, namely, that it is possible to speak while wearing it, without disarranging it, and the sound of the voice is very slightly obstructed in its passage through the outlet valve.

The following table showing the proportions of oxygen and carbonic acid in different samples of air is printed, as it will probably be interesting in connection with the foregoing remarks. The figures are kindly furnished by Mr. Dent, Assistant in the Chemical Laboratory of the Royal Arsenal, and though the table is small it has taken some weeks' labour to trace out. It is interesting to notice the very narrow limits within which ordinary life is supported, as few have passed through railway tunnels without suffering some inconvenience.

TABLE.

	Oxygen. Per cent.	Carbonic acid. Per cent.
Hills, Scotland	20·980	·0332
London Parks	20·950	·0394
London, average of 68 analyses	20·885	·0439
Glasgow, open places	20·929	·0461
" closer ditto	20·889	·0539
Metropolitan Railway Tunnels	20·700	·1452
Theatres, worst places		·3200
Mines, average of 339 analyses		·7850

J. E. G.

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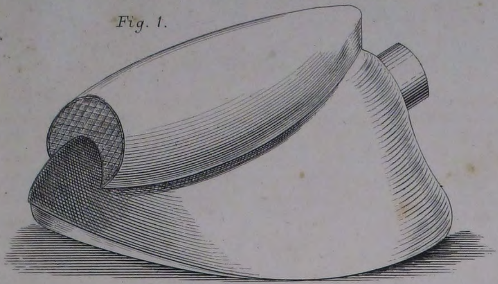
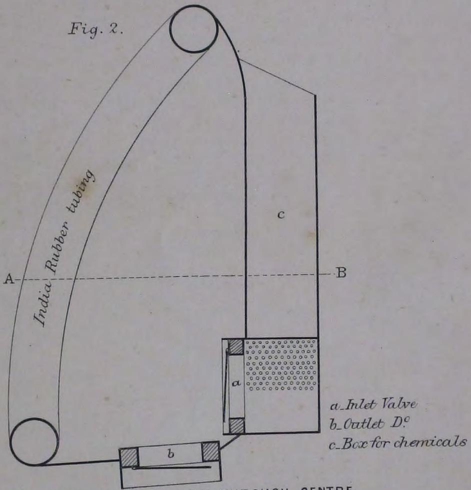
RESPIRATOR FOR MINES. Pl. XXII.

Fig. 1.



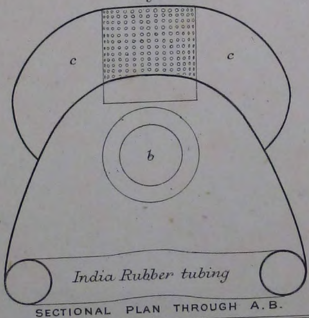
GENERAL VIEW.

Fig. 2.



VERTICAL SECTIONAL ELEVATION THROUGH CENTRE.

Fig. 3.



SECTIONAL PLAN THROUGH A. B.

Kell, Bro? Lithrs London.