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PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS,

CONTRIBUTED BY

OFFICERS OF THE ROYAL ENGINEERS.

NEW SERIES.

VOL. XIV.

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1865.

PREFACE.

The issue of the present Volume has been somewhat delayed by waiting for the receipt of the last paper, which contains the account of a personal visit made by an officer of Engineers to the Defences of Petersburg.

General Gillmore's work on the Engineer and Artillery operations against the Defences of Charleston having been supplied to all the Royal Engineer Libraries, it has not been considered necessary to make any extracts from it, as it is accessible to the majority of our officers.

Papers II, IV, and part of V, were read and discussed at the occasional meetings commenced at the War Office in the present year. The short-hand writer unfortunately lost a large portion of his notes of the discussion on Paper II. These meetings are about to recommence, and officers having Papers they wish to read or to be read are requested to communicate with me as soon as possible. A considerable portion of the sum subscribed at the commencement of the year for conducting the meetings being still unexpended, it will be unnecessary to ask for new subscriptions for the year 1866.

A summary of the experiments on Iron Armour Plates, up to August last, will be again found in Paper XI.

The subject of the Application of Iron to Casemates, &c., will be found extensively treated in Paper V.

C. S. HUTCHINSON,
Captain, Royal Engineers,
Editor.

Woolwich Common,
October, 1865.

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SHEWING THE PRINCIPAL RESULTS

OF

ARTILLERY FIRE AGAINST IRON ARMOUR,

AS DETERMINED BY EXPERIMENTS

CARRIED ON IN ENGLAND IN RECENT YEARS, UP TO AUGUST, 1864.

COMPILED BY

CAPTAIN INGLIS,

ROYAL ENGINEERS.

No.	Nature of Gun.	Range in yards.	Charge in lbs.	Projectiles.		Ratio of weight of projectile to charge.	Description of Target and Effect Produced.	Approximate velocity in feet per second.		*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	Remarks.
				Nature.	Weight in lbs.			Initial.	Striking.		
1	Sir W. Armstrong's 13·3-in. muzzle-loading wrought iron shunt gun of 22 tons 18 cwt. (commonly called 600-pr.)	3300	70	Cylindrical steel shot, diameter 13·24 in.	603	8·61 : 1	6½-in. Armour backed by 18 inches of Timber on skin and ribs similar to to those of "Warrior." Armour and timber penetrated, and skin and ribs very severely injured. Shot did not pass through.	1158	860	3095	This shot was actually fired at a range of 200 yds. with a charge of 40 lbs., giving a striking velocity equal (by calculation), to what it would have at 3,300 yds. if fired with a charge of 70 lbs.
2	Ditto	2000	70	Cylindrical steel shell, bursting charge 24lbs. diameter 13·24 in.	612·5	8·75 : 1	"Warrior" Floating Target completely pierced—an armour plate blown off, and much other damage done.	1150	938	3739	This shot was fired at a range of 500 yds., with a charge of 51½ lbs., giving a velocity due to 2,000 yds. if fired with 70 lbs., and the shot having grazed before reaching the target it is probable that its striking velocity was in reality that due to a much greater range.
3	Ditto	1000	70	Ditto	612·5	8·75 : 1	"Warrior" Floating Target completely pierced—great damage done.	1150	1046	4650	
4	Ditto	200	70	Cylindrical steel shot.	612	8·74 : 1	6½-in. Armour and 18 in. of Timber, on skin and ribs of "Warrior"—completely pierced.	1150	1128	5403	
5	Ditto	200	90	Spherical steel shot.	344	3·82 : 1	11-in. Armour Plate unbacked—broken up.	1708	1574	5914	
6	Horsfall's 13·014-in. muzzle-loading smooth-bore gun of 24 tons 15 cwt.	800	74·4	Spherical annealed cast-iron shot.	285	3·83 : 1	"Warrior" Target. Armour broken through, and skin and ribs very severely injured. Shot broke up and remained in timber backing.	1615	1290	3291	

7	Ditto	200	74·4	Spherical cast-iron shot.	279·5	3·75 : 1	"WARRIOR" TARGET completely pierced.	1631	1510	4422	
8	Lynall Thomas's 9-in. muzzle-loading rifle gun.	200	50	Cylindrical steel shot.	330	6·6 : 1	7½-IN. ARMOUR AND 7 IN. OF TEAK on skin and frame of Mr. Samuda's Target. Struck near the edge of a plate, broke in the armour, and fractured skin and ribs.	1250	1220	3408	
9	Ditto	200	50	Cylindrical wrought iron shot (flat head).	302	6·04 : 1	ARMOUR 6½ AND 7½ INCHES THICK WITHOUT BACKING. Struck on joint of two plates, made indents 6 in. and 4 in. deep.—Plates cracked and shot set up 5½ inches.	—	Not taken.	—	
10	Lynall Thomas's 7-in. muzzle-loading rifle gun.	200	25	Cylindrical wrought iron shot, 16·5 in. long.	150	6 : 1	CAPT. INGLIS'S CASEMATE SHIELD, 7-in. iron plank, backed by other planks, indented to a depth of 1·8 in., bulged 1 in. and cracked. Shot set up 6·5 in.	1245	1214	1534	This gun afterwards burst with a charge of 27·5 lbs.
11	Sir W. Armstrong's 10·48-in. muzzle-loading wrought iron shunt gun of 11¾ tons (commonly called 300-pr.)	200	45	Cylindrical steel shot.	301	6·68 : 1	7½-IN. ARMOUR BACKED BY 7-IN. TEAK, on skin and frame of Mr. Samuda's target—circular piece of armour 12·9 in. in diameter driven in to a depth of 6·2 in., and very nearly separated from plate. Inner frame of ship much injured. Shot set up 2·25 inches and cracked.	1328	1287	3460	
12	Ditto	200	45	Cylindrical steel shot.	301	6·68 : 1	MR. CHALMERS'S TARGET, composed of 3¾-in. armour, compound backing 10 in. thick (made up of plates on edge 10 in. by $\frac{7}{18}$ in., and timber 10 in. by 5 in.), inner armour 1¼ in., teak 5 in., and skin and ribs similar to 'Warrior.' Completely penetrated, shot set up 1·93 in.	1328	1287	3460	

No.	NATURE OF GUN.	Range in yards.	Charge in lbs.	PROJECTILES. Nature.	PROJECTILES. Weight in lbs.	Ratio of weight of projectile to charge.	DESCRIPTION OF TARGET AND EFFECT PRODUCED.	Approximate velocity in feet per second. Initial.	Approximate velocity in feet per second. Striking.	*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	REMARKS.
13	Sir W. Armstrong's 10·48-in. muzzle-loading wrought iron shunt gun of $11\frac{3}{4}$ tons (commonly called 300-pr.)	200	45	Cylindrical steel shot, diameter 10·46 in.	301	6·68 : 1	"LORD WARDEN" TARGET, composed of $4\frac{1}{2}$-in. armour, 10-in. teak, $1\frac{1}{2}$-in. iron skin, $12\frac{1}{2}$-in. ship timbers, and 8-in. inner planking. Completely penetrated.	1285	1250	3264	
14	Ditto	200	35	Cylindrical steel shot.	297	8·48 : 1	"SMALL PLATE" TARGET composed of $5\frac{7}{8}$-in. armour and 2 ft. 3 in. of timber, completely penetrated.	1130	1095	2471	
15	Ditto	200	45	Cylindrical cast-iron shot, diameter 10 4 in.	307	6·82 : 1	CAPT. INGLIS'S CASEMATE SHIELD: struck junction of 7-in and 8-in. iron planks backed by other planks, made indents 1·3 and 2 in. deep. Plank cracked and shield bulged.	1255	1222	3181	
16	Ditto	200	45	Ditto	230	5·11 : 1	SAME SHIELD—Struck an 8-in. plank backed as before, and made indent 1·45 in. deep. Plank cracked and shield bulged.	1445	1395	3106	
17	Ditto	200	35	Cylindrical cast-iron shot.	308	8·8 : 1	"BELLEROPHON" TARGET, composed of 6-in. armour, 10-in. timber, skin $1\frac{1}{2}$ in. thick, and strong ribs, stringers, &c. Armour indented 1·6 in , bent and cracked.	1125	1090	2540	

18	Ditto	200	35	Ditto	308	8·8 : 1	"SMALL PLATE" TARGET, composed of 5⅞ (or 4¾) in. armour, and 2 ft. 3 in. of timber: struck on joint of plates, drove in a piece of 5⅞-in. plate to a depth of 9 in., and bent in a corner of 4¾-in. plate. Shot broke up.	1125	1090	2540	
19	Ditto	200	45	Cylindrical steel shell with light cast-iron head, bursting charge 11 lbs.	288	6·4 : 1	5½-IN. ARMOUR BACKED BY 9 IN. OF TEAK on skin and frame of Mr. Samuda's target. Armour pierced and shell burst in backing, tearing away inner skin, breaking a rib and doing other injury. Fragments carried in board.	1356	1312	3440	
20	Ditto	200	35	Cylindrical steel shell with light iron head, bursting charge 12¾ lbs.	301	8·6 : 1	MR. CLARK'S TARGET, composed of 4-in. armour, compound backing of iron and millboard 7½ in. thick, skin and ribs. Large hole made completely through the target and great number of fragments passed in board. Part of shell remained in the hole.	1135	1100	2527	
21	Ditto as smooth bore.	200	50	Spherical steel shot, diameter 10 43 in.	168·25	3·36 : 1	"SMALL PLATE" TARGET, composed of 5⅞-in. (or 4¾-in.) armour, and 2 ft. 3 in. of timber: struck partly on 5⅞ and partly on 4¾-in. plate, completely penetrated. Shot broke into several pieces.	1715	1576	2900	
22	Ditto	200	50	Ditto	168·25	3·36 : 1	"LORD WARDEN," composed of 4½-in. armour, 10-in. teak, 1½-in. inner iron skin, 12½-in. ship's timber, and 8-in. planking. Hole through armour 11½ in. by 11 in., and some injury in rear. Shot remained unbroken in the backing.	1715	1576	2900	

No.	Nature of Gun.	Range in yards.	Charge in lbs.	Projectiles.		Ratio of weight of projectile to charge.	Description of Target and Effect Produced.	Approximate velocity in feet per second.		*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	Remarks.
				Nature.	Weight in lbs.			Initial.	Striking.		
23	Sir W. Armstrong's 10·48-in. muzzle-loading wrought iron shunt gun of 11¾ tons (commonly called 300-pr.) as a smooth bore.	200	50	Spherical steel shot, diameter 10·324 in.	168·25	3·36 : 1	Mr. Clark's Target, composed of 3-in. armour, compound backing 6½-in. thick, and skin and ribs. Completely penetrated, and great number of fragments carried in board. Shot altered in form to 10·92 by 9·28 in.	1715	1576	2900	
24	Ditto	200	35	Spherical steel shot, diameter 10·43 in.	168·25	4·8 : 1	"Bellerophon" Target, composed as described in No. 17. 6-in. armour pierced, and injury done to skin, ribs, &c. Shot altered in form to 11·179 by 9·456 in. buried in wood backing.	1600	1470	2523	
25	Ditto	200	50	Spherical wrought iron shot.	162	3·24 : 1	Mr. Scott Russell's Target, composed of 4½in. armour, three thicknesses of inch-plate, and strong skin and ribs. Hole pierced completely through the target but shot bounded back itself.	1720	1580	2806	
26	Ditto	200	45	Ditto	163	3·62 : 1	7½-in. Armour unbacked, indented 3¾ in. deep, diameter of indent 13 in., with crack on face, and bulge and star in rear. Shot flattened to diameter of 13 inches.	1750	1610	2932	

27	Ditto	200	50	Spherical cast-iron shot, diameter 10·369 in.	150	3 : 1	"MINOTAUR" TARGET, composed of 5½-in. armour, 9-in. teak, and skin and ribs as in the "Warrior." Completely penetrated.	1766	1620	2731
28	Ditto	200	50	Ditto	150	3 : 1	"WARRIOR" TARGET. 4½-inch armour broken through and skin slightly bulged. Shot broke up and remained buried in timber backing.	1766	1620	2731
29	Ditto	200	50	Ditto	149·6	2·99 : 1	MR. CHALMERS'S TARGET as described in No. 12. Hole through 3¾-in. armour 1 ft. 2 in. by 11 in.; shot broke up and buried itself 1 foot deep in the backing. 2 ribs broken and skin bulged.	1766	1620	2724
30	Ditto	200	35	Ditto	149·6	4·27 : 1	MR. CHALMERS'S TARGET, as above, indent 3·3 inches deep in face of armour, and plate bent 7 inches in length of 4 feet, and other injuries. Shot broke up.	1700	1547	2484
31	Ditto	200	35	Ditto	149·6	4·27 : 1	"BELLEROPHON" TARGET, as described in No. 17. 6-in. armour, indent 5 in. deep. Plate cracked and skin bulged.	1700	1547	2484
32	9·22-inch muzzle-loading shunt gun of 12 tons 2 cwt.	200	44	Cylindrical steel shot, diameter 9·14 in. length 13·42 in.	221	5·02 : 1	"LORD WARDEN" TARGET, as described in No. 13, completely penetrated, and shot passed afterwards 500 yds. out to sea. Shot increased to 10·005 inches diameter and reduced in length to 11·8 in.	1524	1450	3224

No.	NATURE OF GUN.	Range in yards.	Charge in lbs.	PROJECTILES.		Ratio of weight of projectile to charge.	DESCRIPTION OF TARGET AND EFFECT PRODUCED.	Approximate velocity in feet per second.		*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	REMARKS.
				Nature.	Weight in lbs.			Initial.	Striking.		
33	9·22-inch muzzle-loading shunt gun of 12 tons 2 cwt.	1200	44	Cylindrical steel shot.	221	5·02 : 1	"SMALL PLATE" TARGET, as described in No. 18. $4\frac{3}{4}$-in. plate struck; target completely penetrated, and indent ·3 in. deep made on another target in rear.	1500	1300	2591	This shot was fired at 200 yards range, with a charge of 30 lbs., giving by calculation a velocity equal to that of same shot at 1,200 yards if fired with a charge of 44 lbs.
34	Ditto	200	44	Cylindrical hollow shot of chilled cast-iron.	258·75	5·88 : 1	"SMALL PLATE" TARGET as in No. 18. $4\frac{3}{4}$-in. plate, struck, and target completely penetrated. Large timber knee carried away. Shot broke up in passing through.	1410	1355	3296	Very similar effect afterwards produced with a 30-lb. charge.
35	9·22-inch muzzle-loading shunt gun of 12 tons 2 cwt.	200	30	Cylindrical steel shot, diameter 9·14 in.	221	7·36 : 1	"SMALL PLATE" TARGET, as in No. 18. $5\frac{7}{8}$-in. plate struck, and target completely penetrated.	1300	1255	2415	
36	Ditto	200	30	Ditto	221	7·36 : 1	"SMALL PLATE" TARGET, as in No. 18. $4\frac{3}{4}$-in. plate struck, and target completely penetrated; considerable indent made on another target in rear.	1300	1255	2415	
37	Ditto	200	30	Cylindrical steel shell, bursting charge 11 lbs.	217	7·23 : 1	"SMALL PLATE" TARGET, as in No. 18. $5\frac{7}{8}$-in. plate struck, and target completely penetrated. Shell burst in passage and did general injury to target.	1300	1255	2371	

38	9·22-inch muzzle-loading shunt gun of 6 tons 11 cwt.	200	20	Cylindrical steel shell, bursting charge 7½lbs.	182·5	9·12 : 1	"LORD WARDEN" TARGET as described in No. 13. Hole 12½ in. by 11½ in., broken through the 4½-in. armour and forced into backing. Shell broke in two pieces.	1035	1002	1271	
39	Ditto	200	25	Spherical steel shot.	114·25	4·57 : 1	"LORD WARDEN" TARGET as in No. 13. 4½-in. armour penetrated, and shot unbroken, buried in 10-inch timber backing.	1572	1424	1607	
40	Ditto	200	25	Spherical shot of chilled cast-iron, diameter 9·17 in.	103·75	4·15 : 1	"LORD WARDEN" TARGET as in No. 13. Piece (13 in. by 11 in.) of 4½-in. armour forced into backing. Shot broke up.	1694	1507	1635	
41	Whitworth's 6·4 to 7-in. gun of 7 tons 8 cwt. (commonly called 120-pr.)	800	27	Cylindrical homogeneous metal shell, (flat head), bursting charge 5 lbs.	151	5·59 : 1	TARGET OF "WARRIOR" CONSTRUCTION, except as to armour, which was 5 in. thick, completely penetrated. Shell burst in timber backing and did great injury inboard.	1360	1165	1422	No Fuze used.
42	Ditto	800	27	Cylindrical homogeneous metal shell (flat head), bursting charge 3½lbs.	130	4·81 : 1	TARGET OF "WARRIOR" CONSTRUCTION, except as to armour, which was 5 in., completely penetrated. Shell burst at back of skin and carried great number of fragments inboard.	1462	1238	1382	No Fuze used.
43	Ditto	600	25	Ditto	130	5·2 : 1	"WARRIOR" TARGET. Completely penetrated. Shell burst in backing.	1410	1263	1439	No Fuze used.
44	Ditto	200	27	Cylindrical steel shell bursting charge 5½lbs.	149·5	5·53 : 1	"BELLEROPHON" TARGET, as in No. 17. 6-in. armour pierced and shell burst in backing. Skin bulged, rib bent, and other injury done.	1350	1275	1686	No Fuze used.

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No.	NATURE OF GUN.	Range in yards.	Charge in lbs.	PROJECTILES.		Ratio of weight of projectile to charge.	DESCRIPTION OF TARGET AND EFFECT PRODUCED.	Approximate velocity in feet per second.		*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	REMARKS.
				Nature.	Weight in lbs.			Initial.	Striking.		
45	Whitworth's 6·4 to 7-in. gun of 7 tons 8 cwt. (commonly called 120-pr.	200	25	Cylindrical homogeneous metal shell (flat head), bursting charge 5¾lbs.	148	5·92 : 1	5½-IN. ARMOUR BACKED BY 9 IN. OF TEAK, on skin and frame of Mr. Samuda's target, as in No. 19. Struck close to hole made by No. 19, punched a hole 9½ in. by 9 in, through armour, and burst in backing without doing much more injury.	1335	1260	1630	
46	Ditto	800	27	Cylindrical homogeneous metal shot.	129·5	4·79 : 1	TARGET OF "WARRIOR" CONSTRUCTION, except as to armour, which was 5 in. Completely penetrated.	1430	1200	1294	
47	Ditto	200	25	Cylindrical shot of Frith's steel (flat head).	150	6 : 1	CAPT. INGLIS'S CASEMATE SHIELD.—Indent 3 inches deep in an 8-in. iron plank backed by other planks; large portion of shot remained imbedded. Target in rear cracked and bulged	1310	1235	1587	
48	100-pr. smooth-bore wrought iron gun of 6 tons 10 cwt.	200	25	Spherical cast-iron shot, diameter 9·13 in.	102	4·08 : 1	MR. CLARK'S TARGET, as in No. 20. Hole 9½-in. diameter, made through 4-in. armour, and shot buried 11½-in. deep in compound backing; skin and ribs cracked. Shot broke up.	1660	1510	1613	

49	Ditto	200	25	Spherical wrought iron shot, diameter 9·16 in.	113	4·52 : 1	CAPT. INGLIS'S CASEMATE SHIELD—Indent 2·4 inches deep in 6-inch plank, backed by other planks, and target slightly bulged in rear; diameter of shot increased to 12·2 in.	1548	1442	1630	
50	7-in. muzzle-loading shunt gun of 6 tons 13 cwt.	200	25	Cylindrical steel shot, diameter 6·91 in.	100	4 : 1	"LORD WARDEN" TARGET, as in No. 13. 4½-in. plate and 10-in. backing penetrated, and 1½-inch iron skin indented 1 in. Shot set up 1·39 in.	1580	1497	1555	
51	120-pr. Armstrong muzzle-loading shunt wrought iron gun.	400	18	Cylindrical cast-iron shot, diameter 6·94 in.	126	7 : 1	THORNEYCROFT 10-INCH SHIELD, composed of tongued and grooved bars 10 in. by 4 in. Broke away 2 ft. 9 in. of bar, and drove it 10 yds to the rear with other injury. Indent 2·2 inches.	1250	1185	1227	
52	7·1-in. Ordnance Select Committee gun.	200	16	Cylindrical steel shell (flat head with false cap), bursting charge 2 lbs. 4 oz.	119	7·43 : 1	"BELLEROPHON" TARGET as described in No. 17. 6-inch armour indented 1 inch, diameter of indent 8½ inches. Plate bulged 1·4 inch.	1367	1257	1304	The false cap came off at the muzzle.
53	7-in. Armstrong breech-loading rifled gun of 81·5 cwt., (commonly called 110-pr).	200	14	Cylindrical steel shot, slightly concave head, diameter 7·064 in. length 10·02 in.	110	7·85 : 1	"WARRIOR" TARGET. Shot pierced the 4½-in. armour and remained in the plate with 6·25 inches projecting. Hole in armour 7·75 in. by 7·25 in. Shot set up 1·014 in.	1177	1140	992	Three CAST-IRON shots of the same weight (110 lbs.) fired with 14-lb. charges, made respectively indents 1·3-in., 1·6-in., and 1·9-in. deep, in face of 'Warrior,' and three of the same shot striking close together made a hole 18 in. by 9 in. in the 'Warrior's' armour.
54	Ditto	200	12	Cylindrical steel shot, diameter 7·04 in.	110	9·16 : 1	"SMALL PLATE" TARGET as in No. 18. Made indent 2·8 inches deep in 5½-in. armour, and buckled the plate 3 in. Shot set up.	1125	1090	907	

No.	Nature of Gun.	Range in yards.	Charge in lbs.	Projectiles.		Ratio of weight of projectile to charge.	Description of Target and Effect Produced.	Approximate velocity in feet per second.		*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	Remarks.
				Nature.	Weight in lbs.			Initial.	Striking.		
55	7-in. Armstrong breech-loading rifled gun of 81·5 cwt., (commonly called 100-pr.)	200	12	Cylindrical steel shot, diameter 7·04 in.	110	9·16 : 1	5½-in. Plate unbacked. Shot passed clean through and penetrated some 6 feet into earth. Shot little altered in form.	1125	1090	907	110-pr. cast-iron shot indented unbacked plates as follows: 5½-inch ...... 1·9 in. 6½ " ...... 2·0 in. 7½ " ...... 1·65 in.
56	Ditto	200	14	Cylindrical cast-iron shot.	110	7·85 : 1	Mr. Hawkshaw's Shield 6 in. thick, composed of one 1½-in. and six ⅝-in. plates fastened together by alternate 1½-in. rivets, and screws 6 in. apart. Shot passed through, sending a shower of splinters to the rear.	1177	1140	992	
57	Ditto	200	14	Ditto	110	7·85 : 1	Mr. Hawkshaw's Shield 10 in. thick, composed of one 2-in. and thirteen ⅝-in. plates, fastened by alternate rivets and screws 1½ in. diameter, placed 6 inches apart. Indented to a depth of 2·35 in., and target cracked in front and bulged in rear.	1177	1140	992	
58	Ditto	200	18	Cylindrical cast-iron shot, 8 in. long.	68·1	3·78 : 1	Target of "Warrior" Construction, except as to armour which was 5 in. thick. Indented to a depth of 3 inches.	1596	1486	1043	
59	68-pr. Service Gun, 95 cwt., calibre 8·12-inch.	200	16	Spherical steel shot.	71·5	4·46 : 1	"Warrior" Target. Hole broken through 4½-in. armour, and pieces of it driven into teak backing.	1535	1393	963	The cast-iron 68-lb. shot at same range makes an indent 2 inches deep in this armour.

60	Ditto	200	16	Ditto	71·4	4·46 : 1	5½-IN. ARMOUR BACKED BY 18 INCHES OF TIMBER on skin and ribs of "Warrior" Indent 3·8 in. deep.	1536	1394	963	68-pr. CAST-IRON shot at 200 yds., indents 7½ in., armour unbacked to a depth of 1·6 inch.
61	Ditto	200	16	Ditto	71·4	4·46 : 1	"LORD WARDEN" TARGET, as described in No. 13. 4½-in. armour indented 3·6 inches. Armour nearly pierced.	1536	1394	963	
62	Ditto	200	16	Ditto	71	4·43 : 1	"SMALL PLATE" TARGET as in No. 18. 5⅝-in. armour plate indented 3·9 inches and buckled 4 in.	1537	1395	958	
63	Ditto	20	16	Spherical wrought iron shot.	72	4·5 : 1	4-INCH ARMOUR ON A TIMBER SHIP. Side of ship penetrated, and a shower of splinters carried inboard. Shot doubled up.	1528	1515	1146	A CAST-IRON shot at the same range did not penetrate.
64	Ditto	600	16	Ditto	71·5	4·46 : 1	THORNEYCROFT 10-INCH SHIELD, composed of tongued and grooved bars 10 in. by 4 in. Indented 1·75 inch and cracked in rear.	1535	1155	662	
65	Ditto	400	16	Spherical cast-iron shot, diameter 7·91 in.	66·25	4·14 : 1	THORNEYCROFT 8-INCH SHIELD, composed of tongued and grooved bars 8 in. by 3¾ in. Indented 2·8 in., and large piece broken off the rear.	1579	1280	753	
66	Ditto	200	16	Ditto	66·25	4·14 : 1	MR. HAWKSHAW'S 10-IN. SHIELD as in No. 57. Indented 3·15 inches, and shield much cracked both front and rear.	1565	1367	859	
67	Ditto	200	16	Ditto	66·25	4·14 : 1	MR. HAWKSHAW'S 6-INCH SHIELD as in No. 56. Completely penetrated and a shower of splinters carried to the rear.	1560	1367	859	

No.	Nature of Gun.	Range in yards.	Charge in lbs.	Projectiles.		Ratio of weight of projectile to charge.	Description of Target and Effect Produced.	Approximate velocity in feet per second.		*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	Remarks.
				Nature.	Weight in lbs.			Initial.	Striking.		
68	68-pr. service gun, 95 cwt., calibre 8·12 in.	200	16	Spherical cast-iron shot.	66·25	4·14 : 1	'Undaunted,' protected by 3-in. Steel Armour. Pierced ship's side.	1560	1370	863	Similar result on 3-inch wrought iron armour.
69	Ditto	500	16	Ditto	66·25	4·14 : 1	Massive Brickwork protected by 3½-inch Armour. Area 10 in. by 10 in. of plate driven in to a depth of 7 inches.	1575	1220	684	Such a wall reported unequal to resist these shot.
70	Ditto	200	10	Spherical red hot cast-iron shot.	60	6 : 1	'Undaunted,' protected by 2½ in. Steel Armour. Pierced ship's side.	Not taken.	Not taken.	—	
71	Whitworth's 5-in. to 5·5-in gun of 89 cwt. 1 qr. (commonly called 70-pr.)	200	12	Cylindrical homogeneous metal shell (flat head), bursting charge 2 lbs. 6 oz.	68·5	5·7 : 1	4-in. Armour and 9-in. Oak forming front of box, rear of box composed of 2-in. plate and 4-in. oak, sides 4-in. oak. Shell passed through front unbroken, indented the 2-in. plate on rear side and exploded, blowing the box to pieces.	1275	1205	690	No fuze used.
72	Ditto	600	13	Cylindrical homogeneous metal shell (flat head), bursting charge 3 lbs. 12 oz.	81	6·23 : 1	"Warrior" Target. Shell pierced 4½-inch armour, and penetrating 18 in. teak backing, burst, but did not break through the skin.	1260	1102	682	Ditto
73	Ditto	600	13	Cylindrical homogeneous metal shell (flat head), bursting charge 2 lbs. 10 oz.	72·5	5·57 : 1	"Warrior" Target. Shell pierced 4½-inch armour and 11 inches of teak backing and burst, but did no damage to skin or ribs.	1310	1143	657	Ditto

74	80-pr. Armstrong rifled gun of 63 cwt.	400	12	Cylindrical homogeneous metal shot.	78·12	6·51 : 1	"TRUSTY," PROTECTED BY 4-IN. ARMOUR. Ship's side penetrated; piece of plate 21 in. by 11 in. broken in, and many splinters carried inboard. Shot set up from 9¾ in. to 8 in. in length. NOTE.—A similar shot at 200 yds. did similar injury.	Not taken.	Not taken	—	NOTE—A steel flat-headed bolt, weighing 70 lbs., fired with a charge of 12 lbs., from the WHITWORTH 80-pr., made indent 2·8 in. in 4½-in. armour protecting side of "Sirius." Shot fell back into water; little damage inboard.
75	Ditto	400	11	Cylindrical puddled steel shot.	78·4	7·12 : 1	3-IN. ARMOUR ON SIDE OF A 50-GUN FRIGATE. Target completely penetrated. Shot did not break up.	Ditto	Ditto	—	Similar shot of CAST-IRON passed through but broke up.
76	40-pr. Armstrong rifled gun, calibre 4·75 inches.	100	5	Cylindrical steel shot.	43	8·6 : 1	3½-IN. ARMOUR UNBACKED. Completely penetrated.	1233	1210	436	Steel shot of 42·5 lbs., 37·5 lbs., and 34·5 lbs., with 5-lb. charge, did the same.
77	Ditto	100	5	Cylindrical cast-iron shot.	41·2	8·24 : 1	3-IN. ARMOUR UNBACKED. Completely penetrated.	1164	1145	375	Similar shot penetrated 3-inch plate inclined to horizon at angle of 45°.
78	Ditto	200	5	Ditto	40	8 : 1	MASSIVE OAK PROTECTED BY 2½-IN. ARMOUR. Shot pierced armour and drove splinters 8 in. into the oak.	1165	1125	351	
79	Ditto	600	5	Ditto	41·3	8·26 : 1	MASSIVE BRICKWORK PROTECTED BY 3-IN. ARMOUR. Piece 12 in. by 5 in. driven in to a depth of 4 in., and very nearly separated from plate.	1200	1077	332	Such a wall reported equal to resist these shot at 600 yds.
80	32-pr. service gun, 56 cwt., calibre 6·41 inches.	200	10	Spherical cast-iron shot.	31·37	3·13 : 1	"UNDAUNTED," PROTECTED BY 2½-IN. STEEL ARMOUR. Completely penetrated.	1690	1450	457	
81	Ditto	200	10	Spherical cast-iron shell, bursting charge 1 lb.	22	2·2 : 1	"UNDAUNTED," PROTECTED BY 3-IN. STEEL ARMOUR. Completely penetrated.	2030	1650	415	
82	Ditto	100	10	Spherical cast-iron shot, diameter 6·17 in.	32	3·2 : 1	4-IN. ARMOUR ON A TIMBER SHIP'S SIDE. Piece of armour 7·25 in. diameter, driven in to depth of 3½ in.	1690	1560	540	Similar shot at 20 yds. did much the same damage.
83	25-pr. Armstrong breech-loading gun.	100	3·12	Cylindrical cast-iron shot.	24·81	7·95 : 1	2·65-IN. ARMOUR UNBACKED. Penetrated.	1142	1117	214	

No.	NATURE OF GUN.	Range in yards.	Charge in lbs.	PROJECTILES. Nature.	PROJECTILES. Weight in lbs.	Ratio of weight of projectile to charge.	DESCRIPTION OF TARGET AND EFFECT PRODUCED.	Approximate velocity in feet per second. Initial	Approximate velocity in feet per second. Striking.	*Vis Viva* in projectile at instant of impact in tons raised 1 ft. high.	REMARKS.
84	25-pr. Armstrong breech-loading gun.	600	3·12	Cylindrical cast-iron shot.	24·7	7·91 : 1	MASSIVE BRICKWORK, PROTECTED BY 2-IN. ARMOUR. Plate indented to depth of 2·06 in.—piece very nearly broken away.	1145	1015	176	A brick wall of this description, protected by 2½-in. armour, reported equal to resist these shot at 600 yds.
85	12-pr. Armstrong breech-loading gun of 8 cwt. 2 qrs., calibre 3 inches.	200	1·75	Cylindrical steel shot, (flat and round head.)	flat head 11·937 round head 11·875	6·82 : 1 6·78 : 1	2½-IN. ARMOUR, UNBACKED. Penetrated. Shot did not break up. Flat-head Shot—Shortened ·39 in.: original length, 5·92 in. Increased in diameter, ·26 inch. Round-head Shot—Shortened ·14 in.: original length, 6·48 in. Increased in diameter, ·005 inch.	flat-headed shot 1225 round-headed shot 1204	1116 1140	103 107	
86	Ditto	200	1·75	Cylindrical steel shell, (flat head), bursting charge 5 oz. 2 drms.	11·625	6·64 : 1	2-IN. ARMOUR BACKED BY 12 INCHES OF OAK. Penetrated, and shell burst afterwards in rear.	1220	1110	99	
87	Ditto	200	1·8	Cylindrical cast-iron shot.	12	6·66 : 1	MASSIVE OAK, PROTECTED BY 2½-IN. ARMOUR. Indented to depth of ·65 in.	1190	1130	106	
88	Ditto	100	1·5	Ditto	11·56	7·7 : 1	2·01-IN. ARMOUR PLATE. Penetrated.	1155	1125	101	
89	Ditto	100	1·5	Cylindrical wrought iron shot.	12	8 : 1	1·5-IN. ARMOUR, INCLINED TO HORIZON AT ANGLE OF 45°. Penetrated.	1150	1120	104	A cast-iron shot also penetrated.
90	12-pr. Whitworth breech-loading gun of 9 cwt. 3 qrs., calibre 2·73in. to 3in.	200	1·75	Cylindrical homogeneous metal shot (flat head).	12·06	6·89 : 1	2½-IN. ARMOUR, UNBACKED. Penetrated and fell 20 yds. to the rear; shot set up ·6 inch.	1375	1264	133	5 out of 6 of these shot broke up, but when the striking velocity was reduced to 1120 ft. they did not break.
91	Ditto	200	1·75	Cylindrical homogeneous metal shell (flat head), bursting charge 6 oz.	12·15	6·94 : 1	2-IN. ARMOUR BACKED BY 12 IN. OF OAK. Penetrated; shot burst after passing through.	1355	1240	129	No fuze used.
92	6-pr. Armstrong gun.	50	·75	Cylindrical cast-iron shot.	6·25	8·33 : 1	1·06-IN. ARMOUR, UNBACKED. Penetrated.	946	934	38	Similar shot passed through 2 inches of tough cake copper.

T. INGLIS, Capt., Royal Engineers.

PAPER II.

THE INFLUENCE OF RIFLED ORDNANCE ON THE ATTACK AND DEFENCE OF FORTRESSES:

WITH REFERENCE ONLY TO THE FIRST PERIOD OF ATTACK.

(A Paper read at the Occasional Meeting on 7th March, 1865).

By LIEUT. COLONEL GALLWEY, R.E.

It is now generally admitted that rifled ordnance will, with few exceptions, from its superiority in range, accuracy and effect, entirely supersede smooth-bored artillery for all services.

The few remaining advocates for the latter, still cling to its rough and ready nature as better applicable to that " close quarter" fighting, so popular with our Army and Navy, and to its straightness of ricochet, which is supposed to convey the idea that, if a shot fails to hit its mark before the first graze, it may succeed in hitting something before it has stopped bounding and rolling.

The former of these arguments was powerfully wielded, and by distinguished men too, at the time when it became manifest that " Brown Bess" must give way to an arm of greater precision; the close quarter qualities of the latter, however, were well tried by our Infantry at Inkerman, and not found wanting, while its accuracy at long distances furnishes the most convincing argument for a corresponding improvement in Artillery. In the earlier days of the movement when our men were just learning how to shoot with a rifled arm, we were told that our field artillery (than which there was no better in the world) could be silenced by infantry fire at a distance of 600 yards; it was unwelcome news, but still not far from the fact; and the result has been that artillery, by the universal introduction of a rifled gun into our field service, has regained its former pre-eminence and even more than that, because it will be impossible for infantry to advance to the attack of a position defended by rifled artillery in anything approaching close order; even the favourite line formation of our own infantry must give way to one less compact.

Colonel MacDougall in his work " Modern Warfare as influenced by Modern Artillery," dwells strongly on the altered necessities of the attack. At page 414, he writes,—

" One principal effect of the improved fire arms is to give increased importance to the movement of troops in extended order, and to the rapidity of their march, more especially in the case where they are required to assault an enemy's position. It has already been laid down that troops advancing to attack must,—

1st. Adopt that formation which will expose them to the least possible loss from an enemy's fire, while passing over the intervening ground before they can come to close quarters.

2nd. That they shall be exposed to that fire during the shortest possible time."

The arguments then, that have obtained weight in the consideration of the changes necessary in field artillery, will have equal force in deciding on the proper composition of the remaining branches of that service, viz.—siege, garrison, and naval ordnance, until we shall find that the smooth-bored gun is buried in equal oblivion with "Brown Bess," never forgetting, however, the glorious fields of the past that have been won with both.

The object of this paper is to elicit a discussion on the effects likely to be produced by the use of rifled artillery in siege trains, and the armament of fortresses.

Several of our officers have written able articles on the subject, which are to be found in the Professional Papers; and in Vol. XII, new series, there appears a letter from Sir W. Denison, to Colonel Harness, giving a *précis* of probable future siege operations, and urging a fuller treatment of the matter.

The most complete treatise, perhaps, on the subject, is contained in Brialmont's new work on Fortification, in which he analyzes the results of recent operations, and lays down certain leading principles which have manifested themselves to to him, and which are well worthy of attention.

In fact there is no particular branch of the art of war possessing such immediate interest for the military engineer as that comprising the attack and defence of fortresses. This paper then is offered as a refresher or reminder on the subject, and if it succeeds (as it is hoped it may) in provoking a careful professional enquiry into the point at issue, any shortcomings or omissions therein will be amply atoned for.

To proceed:—Fixed principles have been laid down for the guidance of the besieger of a fortified position, which are based on certain assumed conditions, and which have been followed hitherto with more or less success according as these conditions were affected by particular circumstances connected with the place attacked.

These conditions may be briefly stated as follows:—

1st. The besieger must possess a force from three to six times greater than that of the besieged.

2nd. Complete investment so as to cut off all extraneous aid in the shape of men and material from the place attacked.

3rd. The reduction of the artillery fire of the place.

4th. The construction of approaches under cover of which artillery may be brought up and placed in battery, for the purpose of effecting one or more breaches in the body of the place.

5th. The passage of the ditch and crowning of the breach either by assault or otherwise.

Following these principles we are taught theoretically that a first class fortress will fall in thirty or forty days, and actual warfare hitherto has given practical results agreeing generally with the accepted theory.

Possessing this impression of the superiority of the attack, engineers of all nations have been exerting their talents and ingenuity to raise the value of the defence by suggesting improvements in the trace and profile of fortresses.

The main result of these researches has been a division of the great mass of Engineers into two schools, known respectively as the "French" and the "German."

The disputes between these contending parties seem, however, to exaggerate unduly the special advantages stated to exist in the particular system advocated, as also to magnify unduly the faults of the opposite system. It is unnecessary to repeat here the opinions in defence of each system, as they are well known; it is acknowledged, however, by those who pursue the medium course of impartiality, that the true aim of the engineer should be in the first instance—a careful study of the ground to be occupied as regards its configuration and vertical development; and then to apply such a trace and profile as are founded on sound general principles, rather than on any particular system; in fact to fit the work to the ground, and not the ground to the work.

There is not perhaps so great a difference between the adherents of the two schools as their writings would lead us to suppose. In many of the works constructed in France within the last few years, *e.g.*, at Lyons, the French Engineers have adopted the caponier in conjunction with the bastioned trace; while in Germany the theoretical straight front of the polygonal system has been occasionally more or less broken into bastions and curtains.

A striking commentary on the strife for pre-eminence between the two systems is afforded by the siege of Silistria by the Russians in 1854, where the heroic defence of the Arab Tabia, a hastily constructed earthwork, baffled a superior army consisting of 60,000 men, accompanied by a train of 60 siege guns.*

This brief allusion to a notable event, is not in the least intended to disparage well built permanent works, but is rather adduced to show how much the value of a work may be raised (without reference to system), by a determined spirit in the defenders, and we may well be proud that the glorious results obtained in this instance were due in no small degree to the presence and example of a few British officers.

Before proceeding to discuss the effect likely to be produced by the use of rifled artillery, let us glance at some previous experience, and so lead up to the exigencies of the present day. This experience is afforded by the records of actual sieges, as well as by experiments carried on in peace time.

As regards the former, it will not be necessary to enter into the history of siege and garrison artillery, from it earliest introduction; it will serve our present purpose to make such comparisons as will suffice to elucidate the general subject.

In 1819 a committee of British artillery officers recommended that a siege train should consist of 100 pieces of heavy ordnance, and 40 brass mortars, viz.:

Iron.	24-Pr. Guns	40	100
	12-Pr. "	20	
	Howitzers	15	
	Mortars	25	
Brass.	$5\frac{1}{2}$-in. Mortars	20	40
	$4\frac{2}{5}$-in. "	20	

("*Aide Memoire Artillery.*")

* Notes on defence of Silistria, in 1854, by Major Nasmyth, P. P. Vol. VI., New Series.

This recommendation was doubtless based on facts recently acquired during the Peninsula War, as also from the proceedings of other nations in like matters.

The Siege of Antwerp by the French, in 1832, was perhaps the most regular siege carried on during the early part of the present century.

The first batteries were thrown up at a distance of about 600 yards, and the siege proceeded without any marked hindrance to the besieger; the place having surrendered, when a breach had been effected in the escarp of the citadel, after a siege of 24 days.

The causes of the French success are tolerably clear.

1st. The Belgian army was too weak to attempt the defence of the portion of the main enceinte supporting the citadel, and had therefore to retire to the latter work.

2nd. The French had a considerable preponderance of artillery.

At the commencement of the operation, the French siege train consisted of 80 pieces—

24-Prs.	32	80
6-Prs.	26	
8-in Howitzers	12	
10-in Mortars	10	

and before the batteries opened fire, the train was further reinforced by 63 pieces, furnished from different places in Belgium—

24-Prs.	6	63
7-in. Howitzers	8	
10-in. Mortars	30	
4-in. Coehorn	18	
24-in. Mortar	1	

making a total of 143 pieces, of which 94 were mounted in the first period of the attack, and 104 in the second period.*

The armament of the citadel consisted of 147 pieces of ordnance, but that of the front attacked was only as follows:—

24-Prs.	2	39 in all.
18-Prs.	6	
12-Prs.	7	
6-Prs.	10	
8-in. Howitzers	3	
4·5-in. "	3	
13-in. Mortar	1	
Coehorns	7	

a very unequal contest.

General Chassé, in his journal of the defence, testifies on the third day of the siege to the irresistibility of guns of new invention called Paixhan's, the shells from which penetrated bomb-proofs, exploded powder-magazines, and inflicted otherwise extensive damages. The French historian states, however, that Paixhan's shell guns were not used at the siege, and that the results above noted were obtained with the 8-inch brass howitzer, model 1829, adopted by a committee of Artillery officers.

* "*French Journal of Artillery Operations.*"—General Neigre.

The records of this and former sieges shew that the besiegers were enabled to bring into battery guns as heavy as those composing the armament of a fortress; and at Antwerp the French reaped additional advantage from their having been among the first to recognize the importance of improving horizontal shell fire.

During the long peace between 1815 and 1854, considerable progress was made in all countries in rendering horizontal shell fire more effective, as also great strides in the art of casting heavy cannon.

The composition of siege trains was revised; and in France we find the siege train in 1844, composed as follows:—

Brass.	24-Prs.	40	162
	16-Prs.	40	
	8-in. Howitzers	40	
	10-in. Mortars	15	
	8-in. „	15	
	Pierriers	12	

In England, the basis of a siege train consisted of thirty pieces of ordnance—

8-in. gun, 52 cwt.	10	30
24-Pr. „ 50 „	10	
8-in. Mortars	5	
$5\frac{1}{2}$-in. „	5	

(Lefroy's Handbook of Artillery.) These proportions to be increased according to circumstances.

The above-named guns were selected as being the heaviest that could be transported along ordinary roads for the attack of an inland fortress. In addition to these, there were introduced into our service the following ordnance:—

68-Pr. of	112 cwt., 95 cwt. and 88	cwt.
10-inch shell gun	86 „ 84	„
8-inch „	65, 60, 52, 50	„
56-Pr. „	98 and 85	„
42-Pr. „	84, 75, and 67	„
32-Pr.	63, 58, 56, 50, 48, 45, and 42	„
10-inch Howitzer	125	„

In other countries there was a corresponding progress.

All the above calibres were available for garrison defence (although the heavier natures were specially designed for coast and naval armaments), while their great weight precluded the possibility of their forming part of an ordinary siege train. Here then, for the first time, was a decided advantage for the defence, but with the exception of the siege of Sevastopol, no event of importance has occurred in which this advantage has been practically manifested.

We have gained many useful lessons from this siege, where the armaments were far more powerful than those of opposing forces on any former occasion.

The allied forces were enabled, from having command of the sea and from the proximity of their fleets, to bring into battery guns better fitted to cope with the tremendous armament of the place, and which, had Sevastopol been an inland fortress, could not have been accomplished.

It is to be said, however, that the defence was materially assisted by the guns landed from the Russian fleet which was sunk or shut up in the harbour, as Todleben states, Vol. I, p. 313: "On the 26th September, 1854, the armament of the southern side was 172 pieces, and on the 14th October it consisted of 341 pieces, the surplus being nearly all guns of high calibre and long range."

The following abstract of the contending batteries in the first bombardment, is taken from Todleben's account, p. 315:—

RUSSIAN ARMAMENT.

Principal points occupied by Enemy's Batteries.	Canons a bombes 3 pouds.	Canons.				Canons Carronade.			Licornes.*		Mortiers.		Total.	Remarks.
		68	36	24	12	36	24	18	1 poud	¼ poud	5 pouds	2 pouds		
1. French Chersonese	..	1	..	5	..	..	..	..	3	4	...	...	13	64 against French.
2. Do. Mont Rodolphe .	5	..	13	6	6	..	10	..	7	..	1	3	51	
3. English Mnt. Verte	..	2	2	5	..	..	11	4	...	...	1	...	25	54 against English.
4. Do. Mnt. Worontzow	..	2	4	13	..	...	..	...	5	..	...	..	24	
5. Do. above Mikrioukow	..	..	2	..	..	3	..	...	..	..	...	..	5	
	5	5	21	29	6	3	21	4	15	4	2	3	118	

N.B.—1 poud = 36 lbs. Avoirdupois.

"Several other points of the ground in front of our works were defended by 160 guns, of which 33 bore on the Mamelon in front of the Malakoff, and 9 on the heights of the 'Carénage.'"

FRENCH BATTERIES.

Batteries.	Canons.				Canons obusiers, 80 c.	Obusiers, 22 c.	Mortiers.		Total.
	50	30	24	16			27 c.	22 c.	
Mont Rodolphe.									
No. 1	...	7	...	...	2	...	...	...	9
No. 2	...	6	...	...	2	...	...	...	8
No. 3	...	...	...	...	...	...	4	2	6
No. 4	...	...	6	...	...	...	...	2	8
No. 5	...	...	6	2	...	4	...	...	12
Chersonese.									
No. 6	1	...	...	...	5	...	...	...	6
	1	13	12	2	9	4	4	4	49

* Russian howitzer.

ENGLISH BATTTERIES.

Batteries.	Lancaster.		Guns.				Mortars.	Total.
	10″	8″	8″	68	32	24	10″	
Montagne Verte 1	...	1	2	...	...	9	...	12
" " 2	2	...	3	...	...	5	...	10
" " 3	...	...	2	...	...	6	...	8
" " 4	...	...	1	...	...	5	...	6
" " 5	...	...	...	...	...	...	5	5
Mont Worontzow.								
Left face	...	1	7	...	...	2	2	12
Right "	...	...	...	...	7	4	3	14
Left Batt. (Lancaster)	1	...	...	...	...	...	...	1
Right " (les cinq yeux)	1	...	...	4	...	...	...	5
	4	2	15	4	7	31	10	73

Referring to the contest between the Russian and the French batteries, Todleben writes, p. 339, Vol. I: "So that against the French batteries on Mont Rodolphe the Russians had 51 guns against 43
and against those on Chersonese .. 13 " " 6

Total ...... 64 " " 49

and again, "as to calibre, there was an equality, but we had a great advantage, inasmuch that our batteries enveloped those of the French," and "one could not help observing that the disposition of the French batteries was not in accordance with well-known principles. Instead of profiting by the adoption of a trace, which would give a concentrated fire, by throwing up their batteries so as to envelop the works attacked, they grouped their batteries on Mont Rodolphe, delivering a divergent fire on Bastions 4, 5, and 6, and thereby subjecting themselves to a concentrated fire from those works."

"This explains the advantages obtained by our batteries over those of the French, which, after four hours' conflict, were reduced to silence."

Todleben goes on to say, "it was otherwise in our fight with the English batteries, the armament of which was more powerful, and the positions of which had been selected with great skill. The English took care to profit by the advantages conferred by the nature of the ground, and disposed their batteries so as to counterbatter the faces of our works, and at the same time to subject the collateral faces to enfilade and reverse fire."

"The English had

On Montagne Verte.........	41	guns	opposed to	25
On Mont Worontzow	26	"	"	24
Lancaster Batteries	6	"	"	5
	73	"	"	54

"Besides which the English had a decided superiority over us in respect of calibre, and also in their mortar fire. Finally, as above shewn, they had in their favour advantage of position, concentrated fire, command, also the excellent disposition of their batteries, &c.; this inequality was most apparent in the conflict between the Redan (Bastion No. 3), and the batteries on Montagne Verte and Mont Worontzow, in which our works were almost destroyed, and of twenty-two pieces of artillery, twenty dismounted."

"The Malakoff tower was completely destroyed, and the five guns thereon dismounted; altogether thirty of our guns were silenced by the English batteries. Again, these (the English batteries) suffered much less, having only eight guns dismounted, and five platforms damaged."

The French accounts of the first bombardment agree with that given by Todleben, as to the utter inability of their batteries to cope with those of the Russians, owing to the superior armament of the latter. Todleben, in his remarks above noted, states that there was an equality in calibre, but an inspection of the relative statements given by himself, shews a decided superiority in this respect, as well as in number, on the side of the Russians.

Major Elphinstone (English account, part I. p. 32), gives the Russians a more powerful armament than that stated to exist by Todleben, and which he says he has derived from Russian official sources—viz., 109 guns, of which twenty-seven were light pieces, and fifteen did not open on the first day.

The two accounts may be somewhat reconciled by an admission of Todleben's, above given, that "several other points in front of the works were defended by artillery." Accepting Todleben's statement, however, we may arrive at a good estimate of the comparative power of the Russian and English batteries, by striking an average of the calibres used, as follows:—

English Batteries.	Russian Batteries.
42 Guns, 30-prs.	30 Guns, 33-prs.
21 Howitzers or shell guns, 8·4-inch.	23 Howitzers or shell guns, 5-in.
10 Mortars, 10-inch.	1 Mortar, 12-in.
73	54

shewing a considerable preponderance in favour of the English batteries.

Had the French batteries been as successful as the English in the first bombardment, the place must have fallen by assault.

Todleben (vol. I. p 346) gives his opinion, that with the decisive results obtained by the English batteries alone, the assault should have been given, and must have been successful. This is, however, an assertion after the fact.

As the siege progressed, the Russian works were developed and strengthened, and the armament increased, so as to be superior to that of the Allies, so much so, that on the day of the final assault, the Russian artillery was still powerful.

With regard to the French works at the close of the siege, Brialmont in his new work (Vol. III, p. 319), quotes from Marshal Niel as follows:—"If the enceinte had been provided with well revetted scarps, if it had been necessary to make a breach therein in order to penetrate by difficult approaches, and behind which the heads of our columns would have been met by an army, Sevastopol would have been *impregnable*."

"On the 8th September, in fact the day of the final assault, we had only executed, after the greatest efforts, those approaches preparatory to the crowning of the covered way; we had therefore not yet engaged in those works which are the most difficult and dangerous in a siege."

The English works from the nature of the ground and power of the enemy's artillery had not proceeded further than 200 yards from the salient of the Redan.

Sir John Burgoyne ("Military Topics") has ably disposed of a notion, current at the period, of the superiority of earthworks over ordinary permanent works. At p. 192, he writes:—"If the system of earth-works is to be taken as a modern improvement, it must be as compared with that previously established in modern times by military engineers, which implies always, as the rule, parapets of earth and escarp walls well covered from exterior view till only the breadth of the ditch intervenes."

"One of the principal ingredients in defensive works is an obstacle to the approach of the assailants, and the best obstacle is a wall or vertical face to be surmounted. If this exceeds 30 feet in height, and is flanked, it becomes very formidable indeed; an escalade (which while the wall is entire, is the only resource) is the most desperate of all military undertakings, and never succeeds but by absolute surprise or from very great weakness on the part of the defenders. The consequence is, that it is necessary to have recourse to a breach, but in well covered works the breach can only be formed by batteries established at the edge of the ditch," and "after all the breach or breaches being made, he (the besieger) has only the limited extent of those openings as an ingress, whereas the earthworks present one universal breach throughout the whole extent of the place."

The results then of the artillery fighting at Sevastopol prove clearly that a preponderance of calibre on one side or the other produced a dominant effect, and had the Russian works been surrounded with deep ditches and well flanked escarps it would have been madness to assault them as was done on the 8th September, 1855.

We may now proceed to the consideration of rifled artillery.

The following table gives a statement of the siege and garrison rifled artillery available in our service, and in order to facilitate comparison we may assume that other nations will possess armaments of a like nature.

Nature of Gun.	Weight.	Weight of charge.	Weight of shot.	Weight of common shell filled.	Bursting charge of common shell.	Weight of Segment shell.
	cwt.	lbs. oz.	lbs. oz.	lbs.	lbs.	lbs. oz.
7-in. breech-loader......	81 & 84	11 0	110 0	106	8	—
64-pr. —	61	8 0	64 0	64	4½	—
64-pr. muzzle-loader......	65	8 0	64 0	64	4½	64 0
40-pr. breech-loader......	32½	5 0	40 0	40	2½	40 0
20-pr. —	17	2 10	21 0	21	1	21 0
12-pr. —	8½	1 8	12 0	12	—	12 0
9-pr. —	6	1 2	9 0	—	—	9 0
6-pr. —	3½	0 12	6 8	—	—	6 6

Of the above guns, the 7-inch must be excluded by reason of its weight from a siege train unless under exceptional circumstances.

The 64 prs. are also heavier than any gun hitherto included in the composition of a siege train, but in order to compete with the future armament of fortresses, a proportion of these guns must be provided.

This is the more necessary, as it will be possible to use the more powerful guns, viz., 8 inch and 9 inch intended for sea defences, for the armament of fortresses.

The comparative effects of rifled and smooth-bored artillery, have been tolerably well ascertained in our experiments against the towers at Bexhill and Eastbourne in 1860, and against earthworks at Newhaven, in 1863.

At the former of these experiments, three rifled guns were placed in battery at a distance of 1,032 yards from one of the towers on the coast of Sussex, viz.:—

82-Pr. 6-inch calibre—
Charge for shot .... 10 lbs.
Charge for shell.................. 9 „
Bursting charge for shell ...... 5½ „
7-inch Howitzer, throwing shell = 100 lbs.
Charge, 9 lbs.; bursting charge, 8 lbs.
40-Pr.—
Charge, 5 lbs. for shot and shell.
Bursting charge of shell ...... 2½ lbs.

The tower was built of brick, the walls of which, where fired at, were 7 feet 6 inches thick at level of ground, and 5 feet 9 inches at springing of arch, which was 19 feet from the ground, &c. Total height of tower, 31 feet 6 inches.

Sir J. Burgoyne (Vol. X., page 1, P. P. New Series) has given extracts from the reports of the Ordnance Select Committee on these experiments, and it will be only necessary to notice briefly the main results, which are shewn better by the photographs before us,* than by any verbal description. The most decisive result for the number of rounds fired, is shewn in view No. 4, which was taken after the firing of 47 rounds, viz.:—

40-Pr.—	10 solid shot,	1 pl. shell, and	9 live shell.
82-Pr.—	4 "	1 "	13 "
7-In.—	— "	2 "	7 "
	14	4	29

An inspection of this view shews the tower in an untenable state, both as regards the terreplein and the interior, the further expenditure of ammunition as exemplified in view, No. 5, having, for its chief object the trial of percussion fuzes, which at that time, were not in an efficient state.

The Tower selected for practice at Bexhill, was similar in dimensions and general construction to that at Eastbourne. The following guns were placed in battery at a range of 1,032 yards.

Two 68-pr. guns, 95 cwt.; charge, 16 lbs.; shell, 49¼ lbs.; burster, 2¼ lbs.
Two 32-pr. guns, 58 cwt.; charge, 10 lbs.; shell, 22 lbs.; burster, 1 lb.

The photographs† shew the damage done as compared with that inflicted by the rifled guns, viz.:—No. 4 view (Bexhill) should be compared with No. 3 (Eastbourne), and No. 5 (Bexhill) with No. 4 (Eastbourne), and which give indisputable proof of the great superiority of the rifled artillery, even at a moderate range.

Indeed the results obtained with 165 hits from the smooth bored ordnance (No. 9, Bexhill Photographs) cannot compare for effect with those obtained by 47 hits from the rifled guns (No. 4 Eastbourne).

The comparative penetration of solid shot and blind shell are given by the Ordnance Select Committee, as follows:—

Rifled Guns.					Smooth Bored Guns.				
Nature of Projectile.	Weight.	Charge.	Penetration.		Nature of Projectile.	Weight.	Charge.	Penetration.	
	lbs.	lbs.	ft.	in.		lbs.	lbs.	ft.	in.
7-in Shell...	100	9	3	8	68-pr. Shot.	68	16	1	8
6-in Shot ...	82	10	7	6	68-pr. Shell	51	16	1	9
6-in Shell...	77	9	4	3	32-pr. Shot.	32	10	1	4
40-pr. Shot. } 40-pr. Shell. }	41	5	4	1	32-pr. Shell	23½	10	1	4

* See Plates accompanying above-mentioned paper.—Ed.

† It has not been thought necessary to incur the expense of lithographing the Bexhill photographs referred to.—Ed.

The Newhaven experiments have yielded comparative results of the effect of rifled and smooth-bored ordnance against earthworks, which are most interesting.

The guns used were as follows* :—

RIFLED—12-pr., 20-pr., 40-pr., 70-pr., and 110-pr.
SMOOTH-BORED—32-pr., 68-pr., 8-in., and 10-in.

The parapet fired at was thrown up at a distance of 1,060 yards from the battery, and was composed of sandy clay, well rammed, and without embrasures, 25 feet thick at top; exterior slope, 7 feet 5 inches high, to 12 feet in base; interior slope, 9 feet 5 inches high, 3 feet in base.

The following extracts from the report of the Ordnance Select Committee, give the general features of the experiments.

First as to penetration of shot and plugged shell :—

110-pr. solid shot,	penetrated	22	feet
110-pr. plugged shell	„	18·8	„
70-pr. shot	„	17·0	„
40-pr. shot	„	16·4	„
40-pr. plugged shell	„	13·10	„
20-pr. shot	„	11·9	„
20-pr. shell	„	13·3	„
68-pr. shot	„	21·6	„
68-pr. shell	„	14·10	„
10-in. shell	„	11·0	„
32-pr. shot	„	13·0	„
32-pr. shell	„	9·0	„

The shot from the rifled guns were in all cases found to have deviated considerably from a straight line after striking, thus materially lessening their penetration.

The shell firing was carried on principally for the purpose of testing the efficiency of the service percussion fuzes, although the opportunity was also taken for effecting a breach in the parapet.

The number of shells fired were as follows :—

110-pr.	97
70-pr.	27
40-pr.	67
20-pr.	15
10-in. smooth bore	6
68-pr.	12

"The examination at the conclusion of the practice showed the front of the parapet considerably disfigured, in fact it was a mere shapeless mound of earth. The breach on the proper left was enlarged to about 33 feet in width by 5 feet in depth, and the interior of the battery laid open."

This breach was "almost entirely due to the fire of one 110-pr. Armstrong gun, and by the expenditure of 69 rounds (live shell)." "The fire of the 40-pr, 20-pr., and smooth-bored guns had comparatively very little effect."

* See Report of Ordnance Select Committee.

The Ordnance Select Committee draws attention to certain points, amongst which are the following :—

"The best means of destroying an earthen parapet, is by the direct fire of rifled guns throwing shells of large capacity for powder." "One large gun is much to be preferred to several of a smaller nature."

"Relatively speaking, smooth bore guns are of little value for destroying large well constructed earthworks."

These experiments demonstrate, equally with those at Eastbourne and Bexhill in 1860, the great superiority, in accuracy, of rifled artillery, added to which must be considered the additional advantage of increased effect obtained with shells from rifled guns which have considerably larger bursting charges than those from smooth-bored guns of approximate weight, viz.:

68-pr.	95 cwt.	shell	contains	2¼ lbs.
110-pr.	84 "		"	8 "
70-pr.	61 "		"	4¾ "
64-pr.	65 "		"	4½ "
8 inch	52 "		"	2¼ "
40-pr.	32 "		"	2½ "
32-pr.	50 "		"	1⅛ "

In fact, for siege and garrison purposes, the relative value of rifled guns may be determined by the capacity of their shells, which in all probability will be the principal projectiles used in the attack and defence of inland fortresses. Solid shot may be entirely discarded from the stores of such fortresses.

The Ordnance Select Committee points out that it was difficult to obtain the relative contents of the craters in artificial earth, especially when the parapet became disturbed; neither can results be arrived at by considering the relative charges used as mines, as the shells with percussion fuzes burst at about two-thirds of the penetration obtained with them when blind, and again the volume of earth thrown out, will depend in a great measure on the point where the parapet is struck.

One fact was rendered apparent, which was noted by the Ordnance Select Committee. "In breaching an earthen parapet, the fire should be concentrated as much as possible and the breach formed by cutting down the parapet, commencing at the top." "The guns forming a siege train against earthen parapets should fire as large a projectile as circumstances will permit, and as before observed, too great exertions *cannot be made to bring a large gun to the front*—one 110-pr. would probably be equal to a battery of 40-prs."

It has been clearly proved that 25 feet on the superior slope is the minimum thickness that should be given to future parapets designed to resist heavy rifled ordnance; even this has been breached by one rifled gun firing 110-pr. live shells with percussion fuzes, in from three to four hours, as shewn above.

"If there had been embrasures, it would have been done in a shorter time." "A working party, during the day, could not attempt the repair of an earthen parapet under a fire of rifled guns at 1,000 yards, without great loss of life."

The American war has afforded a good stock of information respecting the effect of guns against brickwork.

At the first bombardment of Fort Sumpter, the following guns were placed in battery on Morris Island, the line of fire being inclined to the gorge and right flank (the faces exposed) at an angle of about 60°.

At 4,350 yards,	One 300-pr. Parrott.
" "	Two 200-pr. "
" "	Four 100-pr. "
At 4,100 yards,	Two 200-pr. "
" "	Two 80-pr. Whitworth.
At 3,400 yards,	Two 200-pr. Parrott.
" "	Five 100-pr. "

These batteries opened fire on the 17th August, and continued until the 23rd, during which time the following ammunition was expended:—

	Shot.	Percussion Shell.	Total.
300-pr.	5	286	291
200-pr.	697	1,108	1,805
100-pr.	1,463	2,691	4,154

A total of 863,000 lbs. of metal.

Lieutenant Innes, R.E., who made a personal inspection of the Confederate defences in the harbour of Charleston states (Vol. XIII, P. P., page 18), that "Fort Sumpter is a comparatively modern work, built about the year 1840; it was intended for three tiers of guns, two in casemates and one en barbette; the upper tier of casemates however was never quite completed, and at the commencement of the present war only the lower and barbette tiers were armed."

"The piers and front walls are built of concrete faced with brick, and having tie courses of brickwork run through it at intervals; both concrete and mortar have attained a respectable but not extraordinary degree of hardness. The front wall immediately on each side of the embrasure is 5 feet thick, the general thickness being 8 feet. The piers carrying the bombproof arches are 5 feet thick, the upper arches 2 ft. 3 in. thick, with 3 feet of concrete over; the lower arches 1 ft. 2 in. thick."

The plan and section of the work were shewn to me when I visited the Federal army before Charleston last spring, and from these it appears that the gorge is casemated, but is loopholed for musketry only, front walls 5 feet thick. Lieutenant Innes gives some very interesting facts with regard to the effects produced:—

"Wherever the wall was only 5 feet thick it (the 8-in. shell) invariably came through; as soon as it became apparent that the gorge would be breached, the casemates on that side were filled up solid with layers of sand and cotton, the cotton serving to retain the sand at a much steeper slope than it otherwise would admit of. As the débris accumulated outside, immense numbers of sand bags were thrown over amongst it, so as to form a screen for what remained of the gorge, and now there is scarcely any of the original outer wall visible, the upper part having been shot away and the lower part buried. It being an object to keep the gorge as high as possible, the foot of the breach was never cleared. Had the gorge been much lowered the breaching batteries would have completely searched out the interior of the work." "The interior has suffered much from pitching fire."

"I was shewn one instance in which a 10-inch rifle bolt, striking a pier

8 ft. × 5 ft. (on plan) diagonally, carried away the whole of it, excepting about 18 inches of one corner."

Admiral Dahlgren, in his report of the bombardment of August, states:—"The gorge of Sumpter has been completely ruined by the severe fire of the shore batteries, which has also reached the other faces of the work and must have dismounted most of their barbette guns besides seriously injuring the walls themselves."

Major-General Gilmore, in his official accounts of the siege of Fort Pulaski—a work somewhat similar to Fort Sumpter in general construction—states that a breach was formed in the main walls extending the width of two casemates with an expenditure of about 110,643 lbs. weight of projectiles fired from 84, 64, 48, and 30-pr. rifled guns, and 10-in. and 8-in. columbiads, at a distance of 1,650 yards.

In this case, as at Fort Sumpter, the line of fire was oblique to the face of the wall, nearly 60°. The amount of metal expended in breaching Fort Pulaski was very great, but is explained by General Gilmore as due to the comparative inefficiency of the rifled guns.

The results as regards comparative penetration and effect of rifled and smooth bored ordnance in these operations confirm those arrived at in England. General Gilmore states: "Against brick walls the breaching effect of percussion shells is certainly as great as that of solid shot of the same calibre. They do not penetrate as far by 20 to 25 per cent., but by bursting they make a much broader crater."

We may, from our own experience, go farther and say that shells are more destructive against all material except iron and granite, and with regard to the latter it is probable that by using a proportion of shells a more practicable breach would be effected than if solid shot alone were fired; this, however, remains a subject for experiment.

There has been but little experience gathered in America with regard to the effect of rifle shells on earthworks, owing to the imperfection in the fuzes; in fact, during my recent official visit to that country I failed altogether in collecting information on this subject. For the reason above given, a fuze may be perfectly efficient against timber and masonry, but useless against earthworks, especially at long ranges where the velocity on impact is low. In this country we have attained a very fair degree of perfection in the endeavour to manufacture a fuze which will answer for battering earthworks as well as masonry and wooden ships, and we have now three descriptions of fuze which are efficient against earthworks at a distance of 1,500 yards, viz.:—

The Boxer time fuze for rifled guns.

The Pettman fuze, for rifled or smooth bored guns.

The Armstrong pillar fuze.

It is necessary, however, that in using these fuzes the guns should be fired with full charges, or nearly so, otherwise the pillar or hammer will not be released so as to ensure their action on striking.

This is a difficulty which the Ordnance Select Committee are trying to overcome, as the value of enfilade fire with reduced charges cannot be fully utilised without a fuze of more sensitive action, both on leaving the gun and also on impact.

We have recorded in our Professional Papers many experiments in the way of firing against hidden defences, commencing with the operations in 1824, against the Carnôt wall at Woolwich, and later still at Juliers and other places on the continent.

Sir John Burgoyne remarks with regard to these trials (Vol. X. p. 6, P.P., new series): "This is a practice, however, that will be of very partial utility in real service, inasmuch as it is blindly executed without a sight of the object aimed at, or the slightest knowledge of any errors in firing. At Woolwich, Julier, &c., the distance from the battery to the wall and the height and circumstances of the intervening mass were known to a foot; and after every round, observation of errors in the firing could be, and probably were, made and notified to the battery. Nothing of the kind would be the case at a siege."

We may hold, therefore, while fully admitting the necessity for covering and defilading all masonry as much as possible, such as scarps and caponiers, that a distant bombardment will not enable a besieger to dispense with the necessity of establishing breaching batteries on the crest of the counterscarp, although probably, the effect of such fire will aid in the desired result.

The following table of ranges, &c., of the rifled guns of the service, will assist us in considering their probable effect in action, and also in determining the distance at which works of attack may be placed from a fortress.

Table shewing the mean range, mean difference of range, and mean reduced deflection, of the under-mentioned guns, at 1°, 2°, and 5° elevation, firing solid shot.

Guns.	Elevation.	Mean range.	Mean difference of range.	Mean reduced deflection.	Remarks.
	°	yds.	yds.	yds.	
7-in. breech loader .	1	604	10·4	0·3	Means of 10 rounds.
	2	906	16·7	0·4	
	5	1899	28·0	1·2	
64-pr. breech loader	1	643	5·4	0·4	" 5 "
	2	942	8·0	0·3	
	5	1935	13·2	1·2	
64-pr. muzzle loader	1	762	12·4	0·5	" 5 "
	2	1124	34·0	0·5	
	5	2146	23·4	1·7	
40-pr. breech loader	1	594	11·6	0·53	" 10 "
	2	950·3	16·5	0·53	
	5	1950·3	9·9	1·03	
20-pr. breech loader (live shell.)	1	566·2	13·3	0·43	" 4 "
	2	1078·3	19·4	0·53	" 15 "
	5	2211·7	18·0	1·38	
12-pr. breech loader	1*	704	11·9	0·50	" 10 "
	2	1130·0	12·0	4·0	" 5 "
	5	2146·0	11·0	9·0	

* The practice, at this elevation, was with segment shell.

Let us now proceed to consider how the attack and defence of fortresses will be affected by the introduction of rifled artillery. The first fact that has been made apparent, is the defenceless condition of fortresses and fortified positions in existence prior to the last four or five years, owing to the distance from which they may be bombarded by rifled guns and rendered useless as arsenals, &c., without the necessity of besieging them in regular form. The distance at which such a bombardment could be effected, has been over estimated in many cases, but there is no doubt it would be most telling at 4,000 or 5,000 yards, and could be carried on without molestation from the fire of the place. We, as a nation, may consider ourselves fortunate that the defence of our principal ports has been postponed to the present time, and that we are not now in a condition similar to that of many of the European powers, who, having expended large sums of money on gigantic works, will have to encircle these enceintes with a line of detached works, occupying such vital points as will compel an enemy to undergo the labour and difficulties of a siege in order to effect the reduction of one or more of them. While this requisite expansion of existing or proposed works would imply a difficult and eccentric defence, whether of a continued line or a line of detached works, advantages are conferred on the defence derived from the substitution of rifled for smooth-bored ordnance. The length of the lines of defence may be increased, and therefore the fronts; the intervals between forts may be greater, depending, however, on the nature of the ground; there will be fewer salients inviting attack, and such as exist will be more or less obtuse; the general trace of a line of works will be straighter and less liable to enfilade, affording a powerful direct fire on the field of attack, and compelling the besieger to an increased development of parallels and batteries in order to enable him to secure the advantage of a concentrated fire, which hitherto has been a considerable item in favour of the besieger.

With regard to profile, the introduction of rifled artillery will necessitate more strongly than ever the covering of all brickwork and masonry so as to ensure their protection at least from direct fire with full charges. The works flanking the main ditch are of greater importance than the escarp, whether they be the ordinary flanks of the bastioned trace or the caponier of the polygonal system; a breach may be effected in the escarp, (although, as before noted, such an event is not probable) by firing with reduced charges and increased elevation, but as long as the flanks are untouched, the passage of the ditch will be next to impossible, and if escarps are built "en décharge," this distant breaching may be almost disregarded, as it can never enable the besieger to dispense with the establishment of breaching batteries on the crest of the glacis; the battering sustained by the gorge of Fort Sumpter by the heaviest artillery ever used for siege purposes, affords a good example of the value of the arched escarp.

The caponier of the polygonal system, being a purely defensive work, can be more efficiently protected than the flanks of the bastioned system, which are subject to direct fire from the siege batteries enfilading the faces of the central bastion of the fronts attacked, the flanks of the latter being also taken in reverse from the same batteries.

However, as I have stated at the commencement of this paper, I shall not engage in the comparative merits of the two systems, as this part of the question is independent of the main subject proposed for consideration, and I should rather hear the opinions of others as they are elicited during the discussion, than weary the meeting with a long paper.

The next important point that demands attention is the construction of earthern parapets, which, as proved by the Newhaven experiments, must be of greater thickness than has hitherto been considered sufficient, and also of greater height. Traverses must be provided in greater number on faces exposed to enfilade fire, and be formed of increased dimensions. Casemates *à la Haxo* will be commonly used to protect the armament of the flanks of permanent works as being far more effective than ordinary traverses.

I witnessed some very interesting experiments a short time since at Shoeburyness, which are carried on periodically at that station for the instruction of Artillery officers.

Plate No. I shews the rear elevation of a face enfiladed, and a section through the "bonnette" and traverses.

Practice was made from a distance of 800 yards, with two 7-inch breech-loading guns, one firing with full charges, viz., 12 lbs. of powder and 110 lbs. shot, and the other with a reduced charge of 3 lbs. of powder and 110 lbs. shot. Guns were mounted on ordinary garrison carriages at the embrasures shewn in the drawing. The practice was excellent. The superior slope of the bonnette was struck by several shot, some of which continued their course into the work. One shot, 12 lbs. charge, penetrated about 25 feet of parapet, breaking through into the splinter-proof. (See drawing.) A shot with 3 lbs. charge penetrated traverse A, where it was about 10 feet thick; the gun in No. 3 embrasure was disabled; the path of several shot directly in line with the interior crest were clearly marked on the interior slope.

The limited extent of the Government ground at Shoeburyness does not allow of the bursting of shells of large capacity, but it was manifest that if 7-inch shells with their bursting charges of 8 lbs. had been used on this occasion, the protecting face or bonnette would have been laid open, and the face enfiladed swept clean. It must be said, however, that the result of each shot was reported and all errors corrected; this is, however, a precaution that must always be observed in practice, in order to utilize the ammunition to the fullest extent, and render as much instruction as possible.

This practice shews plainly that when the guns and flanks are not in casemates, there must be a good solid traverse between every two guns.

The defence will possess advantages over the attack in respect of earthen parapets. The parapets of fortresses will have been more carefully constructed and consolidated, while those of the attack, from the additional cover now necessary, will require more time and labour in construction, added to which they will have to be thrown up under an accurate fire. Probably the working parties (on this latter account) could only labour at night, but even then the siege batteries will suffer from the subsequent day's fire, and their completion be considerably delayed. It may also be said that the plunging fire of the place from its command over that of the attack will be more damaging to earthworks, judging from the experience gained at Newhaven, viz., that the best way of reducing an earthen parapet is to cut it down from the top.

Perhaps the most difficult and puzzling of all the accessories of an earthwork are the embrasures.

How to shape them and how to revet their sides, is a matter of frequent enquiry, even with regard to the effect produced by guns firing from them.

Rope mantlets will keep out musket bullets, but would inevitably be swept away by shells fired with percussion fuzes. They should, however, be amply provided.

Without however entering upon the question of the construction of embrasures, I will only say that here again the advantage rests on the side of the defence, owing to the probable employment of iron for the protection of a portion (at all events) of the artillery, in the shape of cupolas or shields.

Now, let us go into the question of relative armament of forts and siege batteries.

A statement of the guns for these services has been already given, and, as before said, the several guns therein are available for either attack or defence, excepting the 7-inch gun, the weight of which precludes its use in a battering train; the 64-pr. is too heavy (taking into consideration the weight of gun and projectiles) to admit it in large proportions, but we may assume, approximately, that a siege train will be composed as follows:—

64-pr.	Guns	20	per cent.
40-pr.	"	40	"
20-pr.	"	20	"
10-in., 8-in., $5\frac{1}{2}$-in.	Mortars	20	"

If it be said, that, what with improvements in locomotion and science in general, guns of greater calibre may be brought into the trenches by a General, whose communications are secure and which communications may consist of railways in good order, we must then allow the defence the benefit of more powerful guns also.

The armament of fortresses will be composed of all the guns in the table given on page 18, viz.:—

7-inch and 64-pr.—For direct and distant fire.

40-pr.—For high flanks and lateral faces of detached works and for flanking casemates.

20-pr., 12-pr.—Where they can be most advantageously placed and used during the progress of the attack and kept in reserve for that purpose.

The above guns will form the offensive armament; for caponiers defending ditches only, a special gun is required whose extreme range in a polygonal front of most modern construction, will be about 500 yards, and in detached works from 50 to 200 yards at the outside. For this service, a light gun of large calibre, throwing a heavy charge of grape or canister with a very small charge of powder, is to be preferred; it should be a breech-loader, to ensure rapidity of fire, but need not be rifled. The recoil of such a gun would be so small that it might be entirely prevented by means of proper compressors, without endangering the stability of the carriage, and the platform should be pivoted to ensure the gun being centred in the embrasure.

In addition, there will be a few mortars, not so much for firing at parapets and approaches, as for searching hollows or ground, unseen from the place.

The existing rules for fixing the number of guns necessary for the defence of fortresses will hardly hold good, under the altered condition of the probable extension of the fronts of fortresses and the introduction of rifled artillery. The rule adopted by the French (see "Artillery" "Aide Memoire"), is expressed in the equation $(m \times 10) + S = x$; where

x = No. of guns required.
m = No. of bastions.
S = Quality of guns for immediate security, which in a

1st class fortress	=	110 pieces
2nd „	=	70 „
3rd „	=	30 „

Captain Hutchinson, in a paper* on the attack of Posen, assumes "That about 900 yards of the rampart of the enceinte bear upon the ground which the besieger's first batteries will occupy, and that, allowing 12 yards per gun, (thus providing ample space for traverses) about 75 will be mounted in this length of rampart. The faces of the two collateral ravelins, of 100 yards each, also view the position of the first batteries, and might be armed with 16 guns, thus making a total of about 90 pieces, many of them of a heavier character than the besieger could employ, and mounted in positions, such, that to silence them by curved or ricochet fire, may be fairly said to be impossible. To counterbatter them with a prospect of reducing their fire in a reasonable time would, it is conceived, require the use of 135 pieces of ordnance or $1\frac{1}{2}$ times their number, the excess being needful to oppose the extra weight of those of the garrison. The faces of the ravelins and their covered ways, adjacent to the axis of the attack, can, as usual, be enfiladed, requiring perhaps 36 guns; some of these being used for destroying the walls of the casemates flanking the ditches of the ravelins, for counterbattering and enfilading the flanks behind these casemates, and for taking in reverse the ramparts of the caponiers. A number of heavy mortars would of course also be provided."

The siege train then necessary for the attack of Posen, should number 171 guns besides heavy mortars, which, with the ammunition and material, would consume an immense amount of transport. The use of iron of sufficient thickness to resist heavy shot, is an advantage that can be enjoyed by the defence alone. Iron covers may be provided in the shape of cupolas or shields, or both.

Captain Steward has been advocating the use of cupolas in coast batteries, and other maritime defences, (Vol. XIII, P. P. new series) and has given an able and successful exposition of their efficiency and economy; he states, "it may safely be asserted that a two-gun turret is an equivalent for six guns behind embrasure shields, arranged for the defence of the same area, and in some cases even eight, where the area to be covered by fire is very extensive, involving, under ordinary circumstances, a battery with several faces."

This is value with reference to lateral range only, supposing the cupola and the shield equally impervious to shot.

* Read at Chatham in 1863, and reprinted in the present volume.

We may ask then, admitting the above comparison, if two guns in a cupola can cover as much ground as six mounted behind shields, what would be the number of guns in ordinary earthern embrasures that would produce an equal effect, looking at the superiority of protection as well as range controlled? The answer might be: if it be admitted that one gun behind a shield is worth three behind ordinary embrasures (as it certainly would be) then the two guns in the cupola would be worth eighteen in earthen embrasures; and this estimate is not extravagant if it be closely examined.

1st.—The cupola gives, supposing it to be placed on the salient of a polygonal fortress, a lateral range of at least 180°.

2nd.—Except while the guns are being pointed and fired, the embrasures (by turning the cupola a quarter of a circle at the most) are secure from the fire of both artillery or musketry.

3rd.—When in the above position, the cupola, guns, and detachment are perfectly safe.

But instead of accepting the proportional value of 2 : 18, let us take it as 2 : 12, and see what is gained.

A cupola intended for the defence of an inland fortress need not be nearly so strong as one required in a maritime fort or battery; the latter should be constructed to withstand the shock occasioned by the heaviest rifled guns capable of being worked on shipboard, the former will have to resist the fire of those guns only which are included in a siege train, the effect of which against iron plates well backed with timber, even with steel shot, may be ignored. A cupola for this service may be built on the system of "La Gloire," in preference to that of the "Warrior."

The principle of the former consists in screwing small plates, say 5 feet by 3 feet, to a wooden backing; that of the latter in having large plates, a wooden backing, and an inner skin of iron all bolted together, the inconvenience of the system being the breaking of the bolts and nuts on the inside.

Small iron plates of the above dimensions and 4 inches thick, screwed to two thicknesses of 9-inch oak, would probably form a target which would be impenetrable by any gun that could ordinarily be brought into the trenches.

The cost of the "Royal Sovereign" cupolas, which hold two 12-ton guns, is stated by Captain Steward to have been £4,500, including very expensive brass fittings. (See note p. 92, Vol. XIII P. P., new series.)

The cost of a cupola for two 7-inch guns, as above proposed, would not exceed £2,000.

Then as to comparative cost at the rate of 2 to 12:—

Cupola	£2,000
Two 7-in. guns and carriages	900
	£2,900
Twelve 7-in. guns and carriages	£5,400
Twelve traversing platforms, curbs, racers, &c...	840
	£6,240

In addition to the above great saving, only 2 gun detachments are required in lieu of 12.

Looking at home, I cannot help thinking that we should save a vast expenditure in guns, and a great deal of money in other ways, if our new land defences were provided with cupolas; there is no other country in the world whose interest in economising men is so great as that of England; much has been said and written antagonistic to the policy which dictated the necessity of fortifying our dockyards, on the score that all our forces would be absorbed in their defence, and that in consequence we should have no army left to fight that battle which must be gained in order to save the capital. Without at all sharing such views, I think the adoption of the cupola system of defence would be the means of obtaining a minimum garrison of security for those places, and set free a considerable mass of men for the army in the field.

Applying the cupola system to the defence of a first-class fortress, let us refer again to Captain Hutchinson's estimate of the armament of the two fronts of Posen, confining ourselves to the artillery mounted on the main work, viz., 75, and compare the cost:—

In Open Embrasures.		In Cupolas.	
75 guns and carriages at £450	£33,750	7 Cupolas	£14,000
Traversing platforms and racers at £70	5,250	14 guns and carriages	6,300
	£39,000		£20,300
Gun detachments, 6 men per gun, 3 reliefs	1,350 men	Gun detachments, 7 men per gun, 3 reliefs	294 men

In the above, the number of guns is as 14 : 75 in lieu of 14 : 84, as previously given, which is nearer 1 : 5 than 1 : 6.

Here is shewn a saving in favour of the cupola system in the proportion of 2 : 1 in money, and of 4½ : 1 as regards men; the superior advantages then of the cupola system seem indisputable, and supposing the premises on which the above reasoning is based, be deemed not precisely accurate or evincing a preference in favour of a comparatively untried system, it must be admitted that there is a sufficient margin in its favour, in the matter of men and money, to demonstrate its superiority under conditions more approximate to equality than those assumed.

The chief argument that may be urged against its adoption, is, that the continuity and rapidity of fire, gained by the greater number of unprotected guns, will be productive of better results than that obtained by the comparatively slower fire of the smaller number.

Granted, of course, so long as the former continue to be serviceable.

The recent operations against Fort Fisher, so far as may be judged from the despatches of Admiral Porter, furnish some information with regard to this point.

It is asserted therein, that the fire of the fort was completely kept under, chiefly by the fire of four Monitors and the Ironsides, at a moderate range from 800 to 1,000 yards, and that after a short time the Confederate garrison had to seek safety in the bombproofs. We may say then, that in this case at all events the fire of a few guns of large calibre, well protected, gained a signal victory over the far greater number of pieces of smaller calibre mounted in Fort Fisher. In fact, owing to the impenetrability of the Monitors, their guns and crews were perfectly safe, except for the short time necessary for firing.

There is no mention of shot or shell entering the ports of the Monitors during the bombardment of Fort Fisher; and as far as I could ascertain, by particular enquiries relative to the naval bombardment of Fort Sumpter, made during my late visit to America, I could gather only one instance where a shot entered the port of a Monitor.

In order to elucidate the progress of the attack, more particularly with reference to the early period when the Artillery combat is most interesting, I have taken advantage of Captain Hutchinson's paper on the attack of polygonal fortresses, and availed myself of the plan of the proposed attack of Posen which is attached thereto, on which are shewn the works of attack as far as the formation of the third parallel.

The first step to be taken (the investment being complete) is the establishment of Artillery and Engineer parks, which must be kept at a much greater distance than formerly, so as to be secure from the fire of rifled guns. On the nature of the ground will depend in a great measure the facility or otherwise of communications with the first parallel and batteries. If the ground be undulating and accidented, the labour of throwing up covered approaches may be more or less dispensed with, according to circumstances.

Next in order come the formation of the first parallel and distant batteries. With regard to these, Captain Hutchinson advocates the construction of the first parallel independent of and considerably nearer to the place than the positions of the first batteries, and assumes a distance of 700 or 800 yards from the salients of the most advanced covered ways, for two reasons; "first, because it is too far from the enceinte and covered ways to expose the working and covering parties to much danger from fire *by night* from rifled muskets; and, secondly, because it is not so far as to prevent a most galling fire being kept up *by day* by good marksmen upon the embrasures of the place. In the execution of the parallel itself there will be hardly much necessity for departing from old rules." "The depth of approaches in exposed positions will too, most likely, be found to require increasing; for, though a garrison would hardly waste ammunition in blowing away the parapet of a parallel, it might with great advantage pitch a few large shells into that of an approach, and make gaps in it which might almost stop the communication until the night permitted its repair."

The above proposal has much to recommend it, but the difficulties are, I think, underrated.

According to Captain Hutchinson's calculations, the besieger's fire will not open until the fifth day; therefore, during the interval of three or four days, at least, the slender and hastily formed parapet of the first parallel will be exposed to the comparatively unopposed fire of the place. The marksmen of the guard of the trenches would, no doubt, keep up an annoying fire on the embrasures, but account must be taken of the counter-approaches and rifle pits of the besieged, which may with impunity, in the early part of a siege, be pushed well to the front, and which would counteract in a great measure the musketry fire of the besieger; and, with respect to the artillery fire of the place, it must be borne in mind that the effect of the large bursting charges of a few rifle shells with percussion fuzes, if they strike the thin parapet of the parallel fairly, will tend to open a wide breach, and at the short distance of 800 yards such a result may be considered certain; and thus, as noted by Captain Hutchinson, the communication would be stopped until night.

Again, the great length of parallel, 3,000 yards, at a distance of only 700 or 800 yards, invites sorties, certainly a dangerous game for the besieged to play, owing to comparative paucity of numbers; but at this period of the siege and with the support of the artillery, sorties would have a fair prospect of success. Look at the distribution of the opposing forces: the besieger has a thin line of men posted under cover along a line of 3,000 yards—the besieged, under the protection of their guns, make a sortie on either flank of the parallel, having to pass over 800 yards of ground only, which could be effected in a shorter time than the concentration of a sufficient force of the guard of the trenches to ensure a repulse. Concentration implies massing, and massing implies exposure to the fire of the place, unless the trenches be very wide and deep.

The besieged know that a flank movement against one or the other of the extremities of a parallel must draw a large proportion of the covering party towards that particular point, and that the progress *en route* of the force making the sortie will indicate the probable locality of the besieger, and serve as a guide for the direction of the fire of the place, so that the latter will have to endure this fire (owing to its accuracy) almost immediately preceding the assault of the trenches.

Accepting as possible the above course of action, it will be more than ever necessary to secure the flanks of parallels by strong and roomy redoubts; the construction of such strongholds, however, so near the place, would be exceedingly difficult (for they could not be completed on the first night), while on the other hand their destruction by the powerful artillery of the besieged would be easy of accomplishment.

The above remarks then represent roughly the objections the besieged might make to so close an acquaintance.

In placing the first batteries, Captain Hutchinson selects positions for counter-batteries at from 1,200 to 2,000 yards, and enfilading batteries between 1,200 and 1,450 yards from the place, "hoping that within these limits sites could be obtained under cover of hedgerows or accidents of the ground, upon which batteries could be constructed almost without the knowledge of the garrison." This is an admission that if the ground were well seen from the place, the batteries must be retired still further.

It certainly is possible and probable too that such cover would be found in front of many fortified positions, but the existence of such cover at the time of attack would imply neglect on the part of the engineers entrusted with the defence of the place, and it is submitted that it were better to spend money in cutting down copses and hedges, filling hollows, &c., so that the offensive fire of a fort may be utilised to the highest degree, rather than in adding outworks for the greater perfection of the close defence. Captain Hutchinson's distances seem however to be well chosen (though 1,200 yards may be unpleasantly near).

There will be great and unavoidable risk in the construction of works at these distances and keeping them in fighting order when complete, but it is doubtful whether any decisive effect would be gained by commencing fire at a greater distance. It must be borne in mind, however, how the French batteries suffered in the first bombardment of Sevastopol, as Brialmont, Vol. III, p. 314, quotes from Niel:—"It (Battery No. 6, at a distance of 1,600 or 1,700 metres) was armed with 50-pr. guns and 80-pr. howitzers, and having on the 17th and 19th October to struggle alone against the fire of 60 guns, it was (as Niel forcibly relates) *écrasée et supprimée.*"

This was with smooth-bored ordnance.

Brialmont, (Vol. III p. 320), proposes the establishment of the first batteries in closed works at from 2,000 to 2,500 metres from the place.

He says:—"In these days artillery is as accurate, and produces greater effect at 2,000 metres, than formerly at 300, we should therefore construct the first batteries at from 2,000 to 2,500 metres; but differing from the practice of Vauban's method of attack, we believe that it is unnecessary to connect these batteries by a trench. In fact at a distance of from 2 to 3,000 metres, it will be easy to keep the guards of the works and the supports out of sight from the place without throwing up earth-cover. Sorties at this distance are not to be feared, and in order to secure the batteries from this danger it will suffice to establish them in closed works."

To be brief, Brialmont proposes that the positions of these works should be those most favourable for artillery fire, they should afford reciprocal support if possible, and be provided with light artillery in caponiers for the defence of their ditches. He advocates also batteries of field pieces capable of rapid movement from place to place, according as their positions may be discovered and rendered untenable. Brialmont, however, supposes the existence of trees, copses, and hedges, behind which his operations may be kept out of sight; but in considering a theoretical attack we should not assume conditions tending to reduce the difficulties of a siege; it is better to view the case in its worst aspect and be prepared to act accordingly, and then local advantages, when they are found to exist, will be appreciated.

He proposes to mount the heavier artillery in the detached batteries "en barbette," considering this method of working guns when at distances beyond the range of grape and musketry, not more dangerous than when firing through embrasures. This latter suggestion it would be impossible to carry into effect. Brialmont does not take into account the fire of common, segment, or Shrapnel shells with time or percussion fuzes, under which the gun detachments could not continue their duties.

With imperfect shells and fuzes, and with a system of artillery inferior in accuracy to our own, the Federals effectually silenced the barbette armament of Fort Sumpter, at distances from 3,000 to 4,000 yards. We may admit, then, the impossibility of sustaining a fire from barbette guns under the fire of the more powerful armament of a fortress at a distance so great even as 2,000 to 2,500 yards.

Confining ourselves to the consideration of these primary works, we must at once see the advantages that will accrue to the defence of a well constructed fortress, suitably armed, in comparison with those hitherto attributed to it by most authors on the subject.

In order to demonstrate this comparison, I have constructed on Plate II a portion of a bastioned enceinte (decagon) and first works of attack, shewn in red lines; the exterior side of the fronts being 375 yards: also a portion of a fortress on the polygonal system (decagon) exterior side 1,000 yards, with works of attack shewn in black lines. The former exemplifying an attack and defence under the old conditions of smooth-bored artillery with first parallel and batteries at 600 yards from the place, and the latter shewing possible contingencies due to the introduction of rifled artillery. It must be evident, from inspection, that the work to be done by the besieger under the new order of things is considerably the more laborious, independent of any precise system of attack. The plan shews the comparative development of the two attacks, in addition to which must be estimated the increased dimensions of parapets, traverses, trenches and magazines.

Having alluded to the positions of batteries, proposed by Captain Hutchinson and Lieutenant Colonel Brialmont, another disposition presents itself, and which seems adapted for the attack of straight fronts and obtuse salients, especially if cupolas be used for covering the guns of the place attacked.

Fig. 2, Plate II, demonstrates by a simple diagram the advantages of cupolas; suppose A B to be a line of defence 1,000 yards long, with cupolas A and B at each extremity, and X, Y, counter batteries, at a distance of 1,500 yards, whose lines of fire will naturally be respectively X A and Y B, but which, at all events, would be declared when these batteries opened fire.

The duty of the artillery officers in the cupolas would then be to direct cupola A on battery Y, and cupola B on battery X, thereby securing the ports from all fire, except that of the riflemen in the trenches, and from this fire the ports of a cupola may always be efficiently protected by the use of rope mantlets fitted on the guns, as the guns are laid from a point above the cupola and not through the port.

If the number of cupolas be greater, it is evident that the best arrangement will be to disperse the guns of the attack in batteries of from three to five guns each, as shewn on Plate II, with a good space between each gun so as to distract the fire of the place as much as possible; it is a plan, however, that will entail still greater labour, as it may be admitted that the preliminary arrangement and extent of work involved in the construction of one battery for 30 guns, will be less than for 10 batteries of 3 guns each.

The batteries are placed at a distance of 1,500 yards from the place, and the positions on which they stand are supposed to be well seen from the fortress; it is questionable whether these batteries should occupy a front longer than what would be necessary for counter-battering purposes—1st. on account of the covering force that would be required, and 2nd. owing to the exposure of batteries, further extended, to the fire of the collateral ravelins (and cupolas also, if such defences exist).

It would seem advisable to delay the execution of batteries to enfilade the main ditch and batter the caponiers until the formation of the second parallel, neither of which can be well attempted until the fire of the place is subdued to a certain extent.

The construction of the first batteries will exercise the ingenuity and resources of the engineer to the utmost, and considering the importance of executing them with rapidity, and at the same time of sufficient solidity, a large proportion of trained sappers should be employed. Every possible device should be made use of to deceive the enemy as to the position of the batteries, by placing them under natural cover should it exist, or by some artificial means.

Brialmont proposes an earthen screen in front of the batteries, in which screen embrasures can be formed when the guns are ready to open fire. The guns to be mounted "en barbette" for the reasons given before.

This arrangement, it is conceived, while adding much to the labour required, would not afford protection beyond the first hour or two; a screen of bushes placed sufficiently close together to act as a blind, and yet open enough to admit of pointing and taking aim, would seem preferable, as shells would pass through such a screen without bursting.

Previous to the construction of the first batteries, a first parallel thrown up, as recommended by Captain Hutchinson, about 800 yds. from the place, would be of great advantage; it would be exceedingly difficult to maintain such a position, especially during the execution of the first batteries, without a great sacrifice of life; but as one of the principal advantages of the besieger is a great preponderance of force, such losses must be looked upon as necessary and minor evils.

As the principal object proposed for discussion has special reference to the armament of the attack and defence, and the great conflict that must ensue before one side or the other gains a marked ascendancy, it is needless for the present to creep closer to the place. Until the fire of the place is subdued, no successful advance can be made, and when we arrive at an approximate conclusion in this respect, we shall see our way more clearly to a further progress.

It is submitted then that the resisting powers of a fortress have been considerably increased,—

1st. By the improvements effected in artillery, which give to the defence a superiority in calibre.

2nd. Owing to the additional labour entailed by the increased development of the works of attack and their additional bulk, necessitating thereby stronger working parties and a stronger covering force.

3rd. By the adoption of cupolas, a measure which recommends itself as enabling the defence of a place to be entrusted to a smaller garrison, as well as on the score of economy.

T. L. G.

DISCUSSION.

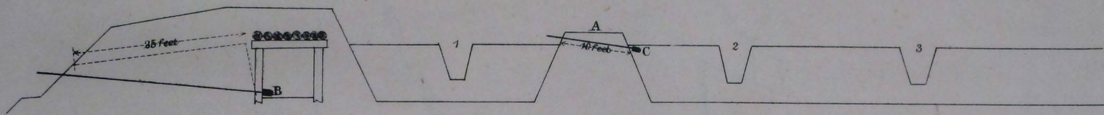
The Chairman (Lieut.-Gen. Sir H. Jones).—I am sure we are very much obliged to Lieut.-Colonel Gallwey for the great trouble and pains he has taken in the preparation of this paper. He has mentioned a great variety of subjects which will come under the cognisance of the debate, and require a good deal of consideration from those officers who have not been able to study the artillery questions to which reference has been made. The paper might, I think, be divided into heads, to enable us to take up the different points seriatim. If any gentleman has any remarks to make we should now be glad to hear them.

The Chairman then asked Colonel Gallwey whether he had divided the subject into heads so that they might be taken seriatim? He replied that he would rather leave it to the meeting.

Colonel Owen.—I did not come prepared to speak, but as no one else seems disposed to take the matter up perhaps you will allow me to offer a few remarks. I will commence by asking Colonel Gallwey if he will be kind enough to state in a few words what are the alterations in the attack of fortresses which he submits for our consideration, because I think the object of our meeting here is to consider the modifications in the mode of attacking fortresses consequent on the introduction of rifled artillery. Now Colonel Gallwey began by giving us an account of the siege of Silistria, where no rifled artillery was used; of the siege of Antwerp where no rifled artillery was used; and of the siege of Sebastopol where no rifled artillery was used. He then advocated the use of cupolas in the defence of fortresses. He then proceeded to discuss a paper of Captain Hutchinson's on modifications in the attack of fortresses, a paper with which I am not acquainted, I am sorry to say. Then he also stated what are Brialmont's views, which are pretty nearly the same as Capt. Hutchinson's. I think therefore we ought to understand what are the principal points which we are to discuss.

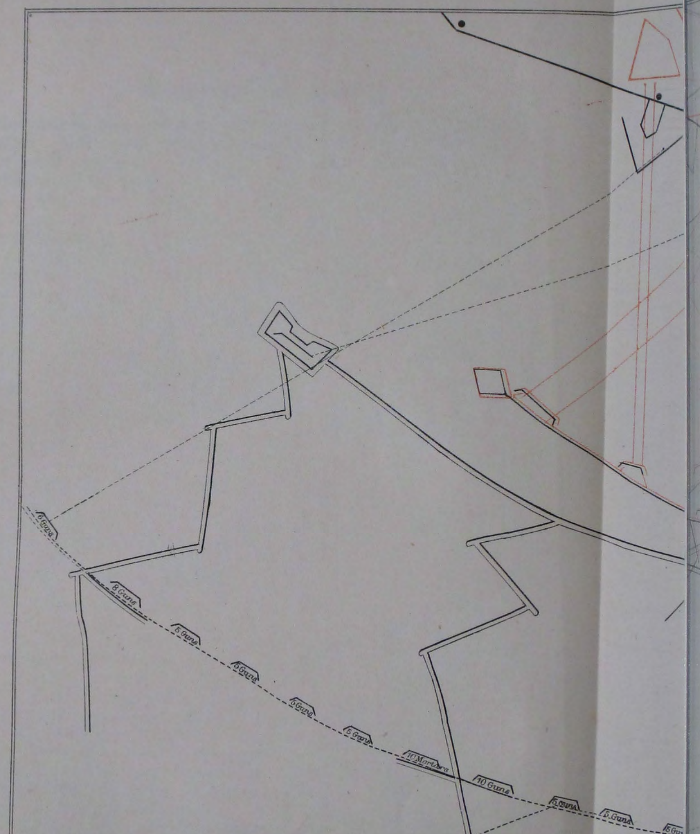
Lieut. Colonel Gallwey.—I have read a very long paper already, the heading of it, the end of it, and the meaning of it is—the influence of modern artillery on the attack and defence of fortresses, especially with reference to the first period of the attack. I have closed the paper asking for information. I brought forward the subject more to get information than to give it. I have taken Capt. Hutchinson's views, and Brialmont's views, and the views of others rather than my own. I merely give a sort of history of the case. I do not presume to give an opinion, I do not consider myself capable of doing so, but I have endeavoured to demonstrate how very superior the effects of rifled artillery are to those obtained by smooth-bored ordnance.

Lieut. Colonel Collinson.—Colonel Gallwey's paper, I think, lays open three or four points for discussion. First of all, whether to use rifled artillery, and what we *should* use; then as to how we should improve our parapets; and thirdly, what effect it would have on the attack and defence. The first point he has almost set at rest. He has settled, I suppose, for all purposes of discussion that the 64-pr. or 70-pr. rifled gun is a siege gun, and I should perhaps open the question whether it is right to consider that as an ordinary siege gun or an exceptional gun; assuming it as an exceptional gun, and not the regular gun, the point to consider is, supposing you have got 40-pdr. rifled siege guns, and 70-pdrs. as exceptional guns, how would you open the attack? Whereabouts would you place your first parallel and batteries? Would you construct them simultaneously? and where would be their relative positions? Perhaps these are the questions we should have put before us to night. I think we should really leave the introduction of iron almost out of consideration. Although it has been mentioned very strongly by Colonel Gallwey, it will complicate the question very much. It is quite legitimate to discuss its effect; but it will simplify the matter if we discuss the opening of an attack on an ordinary existing fortress, and discuss what would be the difference of arming it with rifled guns and using rifled guns in the siege. If we take it upon that basis, I think, and I suppose Colonel Gallwey would allow, that the advantage is in favour of the attack. No doubt it would be absolutely necessary to commence the attack at a greater distance. I think I should be inclined to say that even Colonel Gallwey's distance, and Captain Hutchinson's, is too close. I am much

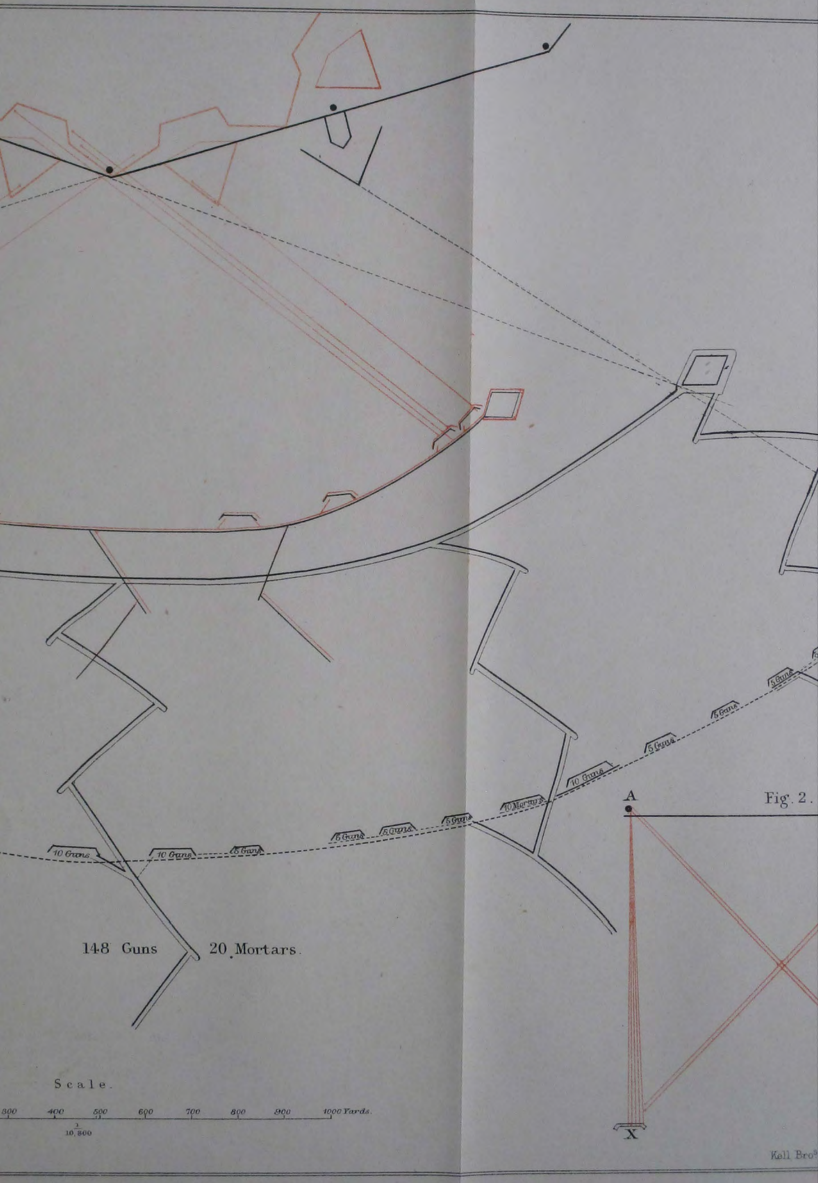


B. 110 P^r. Solid Shot, Charge 12 lbs.
C. D^o D^o D^o 3 lbs.

Kell, Bro^s. Litho, Castle S^t. Holborn.



New Attack; Length of Parallel — 2640 Yds.
Old . . . . — 1780 .
Difference — . 860


10 Guns
10 Guns
5 Guns
5 Guns
5 Guns
5 Guns
10 Mortars
10 Guns
5 Guns
5 Guns
5 Guns
148 Guns
20 Mortars
Scale.
300 400 500 600 700 800 900 1000 Yards.
1/10,800
A
X
Fig. 2.
Kell Bros

inclined to agree with Colonel Gallwey, that the besieged being able to use rifled guns would be able to delay the construction of the first parallel very much indeed, so much so that owing to the waste of time, men, and labour, the besieger would probably find it to his advantage to begin further back. Perhaps if we assume 1,500 yards as a fair distance to open the first battery, there is some point between that and 800 yards on which the first parallel could be constructed. I agree with Colonel Gallwey, that you must spread the first batteries over a greater extent of ground and divide them much more on account of the accuracy of the rifled fire: that leads to requiring a larger army and larger equipments; but providing those exist, it will not increase the time very materially. Supposing however that the besieger is able at that distance to construct his first parallel and his first batteries, the case then is altered very materially and to the advantage of the attack. If, as I said before, we do not introduce iron into the defence, the besieger brings a more effective fire, he has greater resources, and although his guns are of less calibre, he has a greater number of them and of gunners, and soon therefore he opens with a very effective fire, and I think we must allow that the parapets, whether of masonry or earth, in any existing fortresses, with a fire opened from a considerable number of batteries of 40-pdrs. rifled guns, with a few 70-pdrs., would soon be very seriously injured. Of course if you once admit iron into the fortress then that may alter the balance in favour of the defence. But I think that is as the case may be said to stand as far as existing fortresses are concerned. Both as regards attack and defence neither the 40-pdr. nor 70-pdr. has so great an effect upon earth. The penetration of the 70-pdr. was 17 feet; it was only the 110-pdr. that produced a great effect on earth-works. Still the effect on the embrasures of the fortress would be very great as they are so much more conspicuous than those of the attack.

Colonel Simmons.—I think we are very greatly indebted to Colonel Gallwey for having brought this paper before the meeting, in which all the points relative to the first period of the attack have been fairly raised for our consideration. This paper begins with a fair statement of the position of artillery with regard to attack and defence. It seems to me essential before we proceed to consider the measures to be taken in the attack, that we should start from a clearly defined basis on which we should frame our projected attack. That basis entirely depends upon the artillery. Colonel Gallwey assumes that the 64-pdr. is an exceptional gun for attack. From what I have seen I am not prepared to accept that assumption. If we take for instance a fortress constructed on a line of railway, we may be certain that we shall be able to bring up very much heavier guns to the attack than 64-pdrs.; 64-pdrs. are no doubt exceptional guns to accompany ordinary siege trains for the attack of such works as are commonly met with in the field; but when a large fortress is included in the operations of war, and it is decided that an attack is to be made on such a fortress, no doubt the siege train will be accompanied by much heavier guns than by 64-pdrs. If the siege train is to have only 64-pdrs., I think a great advantage is conceded to the defence, which we are not prepared to grant. Very heavy guns have been proved to be very destructive against earth-works, so that batteries for the defence will undoubtedly have far heavier parapets than have ever hitherto been constructed; Engineers must likewise be prepared to adopt similarly larger parapets, which will involve longer time in their construction, for the attack. If we enclose a fortress, and throw up round the fronts to be attacked a sufficiency of these larger batteries, we should be sure now, as formerly, to obtain a preponderance in the attack. The other day at Fort Fisher, an attack was made by ships against a fortress armed with 75 guns, most of them heavy guns; a powerful artillery was brought to bear at ranges of from 1,000 to 2,000 yards; in a very short time the fire of that fortress was completely subdued by the rain of shot poured upon it, according to Admiral Porter's description, at the rate of 115 rounds per minute. Taking this recent fact, and the experience of all former attacks, including the statement Colonel Gallwey produces before us in a very succint form of what occurred at Sebastopol, in which he describes how the Russian batteries preponderated over the French, and our batteries over the Russian by the mere weight of their fire, so whenever an attack takes place the great point will be to bring a sufficiency of guns to bear. There are other points I am not prepared to go into at present. The question is very large, and one to which I think we, as Engineers, cannot devote too much study. But I think as rifled guns have been introduced we must depart from the ordinary means of attack. We must seek some new means. I am not prepared to adopt the cupolas brought forward by Colonel Gallwey, and I think it questionable whether they will be so beneficial as he states on the calculations of Capt. Steward, viz., that one gun in a cupola is worth six in embrasures. It is true the Monitors, with their guns in cupolas, took part in the attack on Fort Fisher; they were backed by a number of other guns, but it is not known exactly what effect they produced. I think means might be found for subduing the fire even of cupolas, if they were adopted in fortresses. I think that if a parallel for musketry can be thrown up at a distance of 900 or 1,000 yds., resort may be had to the old arm, the wall-piece, made with the improvements of the present day. I know that lately I have heard from the very best sources, that before Petersburg, in General Grant's army, the fire of several Confederate batteries had been entirely kept down by wall-pieces. I know the case of an officer who stood himself for some time watching a man who was firing a wall-piece to keep down the fire of a Confederate gun, and who never moved his eye from the telescopic sight for the space of half an hour. I think that tells us that if cupolas are used we must resort to the appliances of the present day to subdue them, and if on a parapet, at a range of 1,000 yds., a number of men were distributed with wall-pieces covering a cupola, and if the moment they got sight of the embrasure several fired, the occupants of the cupola might find themselves in an uncomfortable position. Therefore I am not quite prepared to accept the proposition that a gun in a cupola is worth three or four guns in embrasures. Nor am I prepared to adopt the principle of firing guns out of embrasures. I think from what I have seen, embrasures present constant targets to be fired at; you can always see them; a shell bursting behind an embrasure would do great injury, therefore I think it very doubtful whether we should use embrasures at all. I am not at all clear on the point, I mean in the attack of a large fortress. I do not in this allude to the attack of a small field work. I think it very questionable, in the attack of large fortresses, whether some appliance might not be used by which the guns might be fired over the parapet so as only to be exposed for the moment during which they deliver their fire. I am by no means sure that some contrivance might not be arranged by which the gun might be made to drop down below the parapet after being fired, so as to be completely under cover, and not present any target to the enemy. There is another point also with respect to the working of guns. I think all guns will have to be worked from underneath the parapet by tackle such as is used on board ship. I think that with sundry appliances of that sort, and with some others which might be suggested—it is a subject to which I have not devoted much of my time or attention—the attack might possibly resume its position, and that the fortress would fall, though not probably in so short a period as formerly; but that we might calculate on its falling with tolerable certainty.

GENERAL SIR JOHN BURGOYNE.—I would make one remark which occurred to me while the paper was being read. I hear very imperfectly and have not been able to follow the discussion, but one point struck me as rather novel, viz., in reference to 60-pdrs. and 110-pdrs. being brought into siege batteries. Where you have water carriage you can produce these great weapons; but for sieges in an open country, it is very unusual to carry weapons of this sort. It is not only the carriage of the gun, it is the ammunition, the very great weight of the ammunition. But suppose it comes to the point that you can carry these very heavy guns and bring up the ammunition, it becomes a new element and you have no right to give the rifle all the advantage thereby gained, because the introduction of equally heavy smooth bores would have made a great impression and would have greatly tended to facilitate the operations of a siege.

THE CHAIRMAN.—Perhaps you will allow me to mention an anecdote which appears to me to bear on the subject of cupolas. When the French, in 1810, advanced upon Cadiz and possessed themselves of the Peninsula of Trocadero, excepting the piece of ground on which was situated a small square fort of only 150 feet square, on the two faces, looking towards the Village of Trocadero, were mounted as many guns in embrasures as could be placed in them, excepting at the salient formed by the junction of the two faces, where a gun was prepared on a traversing platform. During the time the enemy was erecting his battery, this gun was not allowed to be used, and was kept in reserve until the enemy should open his fire: on opening his fire, the first shot struck the gun in the muzzle and disabled it; thus all the precautions so carefully taken were rendered of no avail; may not the same thing occur to a cupola battery?

COLONEL SIMMONS.—As illustrating the weight of guns which can be brought by railway to bear in an attack, it will be interesting to officers to know what is actually occurring before Petersburg. There the Federals have a 13-inch mortar mounted on a railway truck specially constructed for the purpose, running along close under their entrenchments, in fact within their entrenchments. Whenever anything serious is going on, a steam engine is hooked on to the truck, and the 13-in. mortar run down to the place, and fire is immediately opened from it on the truck. I have seen a photograph of the mortar on its carriage. The fact is most interesting as showing the weight of artillery which has been brought into the field in an attack, and as demonstrating that the experience of the past is not to guide us with reference to what may happen in the future.

[The discussion was then adjourned till the 27th and 28th April, when it was again continued. The shorthand writer has most unfortunately lost his notes of what was said on these two evenings. It is hoped that he may find them so as to admit of their being printed before the completion of the present volume; if so they will be found further on.—ED.]

PAPER III.

ON THE ATTACK OF POLYGONAL FORTRESSES.*

BY CAPTAIN HUTCHINSON, R.E.

There has been but comparatively little written upon the attack of Polygonal Fortresses. Le Baron Maurice de Sellon, in his "Etudes sur la Fortification Permanente," Captain Mangin, of the French Engineers, in a work translated by the late Colonel Williams, in the third volume of the "Professional Papers," and the late Sir Howard Douglas, in his "Treatise on Fortification," published in 1858, are, I believe, the only authors † who have treated upon it. In the attacks, as proposed by these writers, one of the peculiar features of the polygonal trace, viz., that of bringing to bear a far more powerful fire upon a besieger's first batteries than can be done in a bastioned trace, seems to have been very much lost sight of, and a very inadequate provision, both of time and ordnance, is allowed for the construction and armament of these batteries. Thus Captain Mangin, whose views are more or less adopted by Sir Howard Douglas, commences no batteries till the fourth night of the siege, then proposes to make them in front of his second parallel, at about 400 yards from the ramparts of the enceinte, and to arm counter-batteries for subduing the fire of 300 yards of rampart with eight pieces of ordnance! Well might Colonel Williams remark:—"It is a question whether a besieger would succeed without great loss in time and men, in establishing his first batteries at 327 yards from the most advanced salients, if the ramparts were armed with an effective artillery."

Maurice de Sellon does not hold the artillery of the place quite so cheap as Captain Mangin. In his attack upon Rastadt, as contained in the work before alluded to, he opens his first parallel at 600 metres from the salients of the lunettes in front of Fort Leopold, and, in connection with it, establishes batteries for 165 pieces of ordnance. Of these, however, he directs the fire of only a number of mortars against the enceinte upon which he is approaching, and apparently makes no other provision for silencing its fire, either in the first or second parallel. Again, a strange, and one would almost say reckless, disregard of the artillery of the place.

* This paper was read at one of the Chatham meetings in February, 1863, and was not originally intended for publication in the Corps Papers. From the frequent allusion made to it in Lieut. Colonel Gallwey's paper on "The Influence of Rifled Ordnance on the Attack and Defence of Fortresses," the writer has however thought that it would be better to publish it in the present volume.—ED.

† Brialmont's work had not appeared when this paper was written.

In the remarks which follow, I shall touch mainly upon those points in which the attack of a polygonal differs from that of a bastioned fortress, and upon the changes in the position and armament of the works of attack consequent upon the introduction of rifled arms. I feel very diffident in advancing views which conflict so much with the opinions of the distinguished officers to whom I have alluded; but still, if it is true that the fire of a fortress must be more or less subdued before any close advances can be made upon it, and if Sir John Jones's maxim is received, that in counter-battering there must be, at least, an equality of ordnance between the counter-batteries and the fortress (and with this maxim Crimean experience would seem to accord), I do not see my way to any other conclusion.

Thinking that it would be more interesting to deal with an existing than a theoretical fortress, I have supposed the attack carried on against the town fronts of Posen, consisting of five fronts of an almost regular decagon, with a side of about 540 yards. Each front is provided with a very powerful caponier, extended inwards so as to flank the ramparts, and outwards to act as a redoubt to the ravelin, which latter is salient enough to catch the prolongations of the crests of the enceinte of the collateral fronts. There are masonry block-houses in the salient of each ravelin and its covered way, and also in the re-entering places of arms. The escarp of the body of the place is detached; a covered way and glacis surround the whole of the fronts, and the ditches of the ravelins are flanked by casemates constructed in the escarp of the enceinte, at right angles to their prolongations. I believe that the ground on which these fronts look is tolerably regular in its character, and, that there is nothing to prevent a siege *en règle* from being carried on upon it. Owing to the prominency of the ravelins, and the expediency of exposing the close attack to only two caponiers, I propose to make the axis of the attack on the capital of the second angle of the polygon from its proper left; this will give sufficient room for developing the right flank of the attack without subjecting the batteries there to annoyance from the works on the opposite bank of the river Warthe, on which the left of the town front rests. It is proposed that rifled guns, such as the Armstrong 40-pdr., or heavier ones if the nature of the country admit of their employment, should form the bulk of the siege artillery; and the data which will be assumed as to range are as follows:—for counter-battering an extreme range of 2,000 yards with 5° elevation; for enfilading from 900 to 1,450 yards, with charges of from 2 to $2\frac{1}{2}$ lbs., and elevations of from 5° to 7°. These are numbers which have been given me by practical Artillery Officers. In the ricochet practice from which the above numbers were obtained, 80 per cent. of the shot (or rather shells) fell within the work; and the opinion of the Committee who witnessed the experiments was, that "Armstrong projectiles can be fired at high angles with reduced charges, and still retain precision of direction, and uniformity of range, and are, therefore, well adapted for silencing guns covered by traverses, or for breaching caponiers and sunken defences, but not so well adapted as round shot for making small bounds in a work." * The distance between the first and second grazes, in the practice with the 40-pdr., varied between 800 and 1,180 yards, and the deflection at the second graze, between 38 and 116 yards. It does not appear that sufficient experiments were carried on with smaller charges and higher elevations, to enable any correct results to

* See Professional Papers, Vol. XII, page 36.

be arrived at, except in the case of the 12-pdr. Armstrong gun, where, with a charge of 6 oz., and elevation of 10°, a range of 940 yards, a distance between the first and second grazes of 400 yards, and a deflection at the second graze of 75 yards, were observed.

With regard to the armament of the fortress, I assume that about 900 yards of the rampart of the enceinte bear upon the ground which the besieger's first batteries will occupy, and that allowing twelve yards per gun (thus providing ample space for traverses), about 75 guns will be mounted in this length of rampart. The faces of two collateral ravelins, of 100 yards each, also view the position of the first batteries, and might be armed with 16 guns, thus making a total of about 90 pieces, many of them of a heavier character than the besieger could employ, and mounted in positions such that to silence them by enfilade or ricochet fire may be fairly said to be impossible. To counter-batter them with a prospect of reducing their fire in a reasonable time, would, it is conceived, require the use of 135 pieces of ordnance, or $1\frac{1}{2}$ times their number, the excess being needful to oppose the extra weight of those of the garrison.* The faces of the ravelins and their covered ways, adjacent to the axis of attack, can, as usual, be enfiladed, requiring perhaps 36 guns; some of these being used for destroying the walls of the casemates flanking the ditches of the ravelins, for counter-battering and enfilading the flanks behind these casemates, and for taking in reverse the ramparts of the caponiers. A number of heavy mortars would, of course, also be provided.

The preliminary arrangements having been all concluded in the usual manner, I propose opening the first parallel between 700 and 800 yards from the salients of the covered ways of the ravelins, its right resting on the brow of the hill before alluded to, and its left extending as far as the capital of the collateral ravelin, in round numbers about 3,000 yards; one line of zigzags, which may probably measure another 3,000 yards, should be commenced at the same time; a working party of 3,000 Infantry being required for their execution. I should place the parallel at the position alluded to, for two reasons; first, because it is too far from the enceinte and covered ways to expose the working and covering parties to much danger from fire *by night* from rifled muskets; and secondly, because it is not so far as to prevent a most galling fire being kept up *by day* by good marksmen upon the embrasures of the place. In the execution of the parallel itself, there will be hardly much necessity for departing from old rules; if there is likely to be a glut of gabions, they could, of course, be employed with advantage, or the screens suggested by Captain Tyler might be used. With the approaches, however, particularly those nearest to, or most visible from the place, I should think it would be absolutely necessary to employ gabions, so as to get the men under cover as quickly as possible from the fire of segment or shrapnel shells, which would more or less enfilade the position they occupy.

* Had Posen been a bastioned fortress, and seven bastioned fronts taken the place of the five polygonal ones, about 800 yards of rampart (not exposed to enfilade) of the enceinte and ravelins would bear upon the ground occupied by the besieger's first batteries, requiring, according to the above estimate, about 100 guns to silence the fire of those mounted on this length of rampart. Eight guns in addition would be required to enfilade the faces of the central bastion, making in all 108, a saving of 27 as compared with the number necessary to silence the fire of the polygonal fronts.

The depth of approaches in exposed positions will too, most likely, be found to require increasing; for, though a garrison would hardly waste ammunition in blowing away the parapet of a parallel, it might, with great advantage, pitch a few large shells into that of an approach, and make gaps in it which might almost stop the communication until night permitted its repair; an increase of depth to five or six feet, would be a considerable safeguard against difficulties of this kind.

A protective position having been established, and a means of checking sorties thus provided, the construction of a second line of approach and of elevated batteries (if this nature of battery is required from the circumstances of the site) would be commenced probably on the second night. The position of both counter and enfilading batteries should be selected in rear of the first parallel, at distances from the fortresses varying for the former between 2,000 and 1,200 yards, and for the latter between 1,450 and 1,200 yards. It could hardly happen but that within these limits sites could be obtained under cover of hedgerows or accidents of the ground, upon which the batteries could be constructed almost without the knowledge of the garrison. As for a range of 1,200 yards a 40-pdr. gun requires, with full charge, an elevation of about $2\frac{1}{2}°$, the trajectory of the shot where it crosses the parallel would be about 52 feet above it, and it is not, therefore, likely that any inconvenience would ensue from the counter-batteries being in rear of the parallel, and still less from the enfilading batteries, from which the trajectories are higher. In the case of jacketed shot it might be expedient to remove the guard of trenches from those parts of the parallel over which the fire passes. As it is proposed to allot about 18 guns for counter-battering half of the enceinte of each of the three fronts, whose fire it is considered necessary to silence, this number might, if convenient sites offered, be placed in each of six batteries; most probably, however, smaller batteries would be found more expedient. Two batteries, of 12 guns each, would oppose the fire of the collateral ravelins. Four batteries, two of 10 guns each, and two of 8, with, say, 5 heavy mortars in each, would enfilade the faces of the adjacent ravelins, and counter-batter and enfilade the flanks of the body of the place which sweep the ditches of the ravelins, would also act against the casemates constructed for the same purpose, and take in reverse the ramparts of the caponiers. This would make, in all, 188 pieces, for which battery accommodation is to be provided in rear of the parallel. As, however, the outer faces of the adjacent ravelins, and the extreme half fronts of the enceinte fire only on the extreme flanks of the second parallel, the execution of which flanks might be deferred a night or two after the rest of the parallel, the number of pieces which must open fire before the second parallel is constructed might be reduced to $188 - 48 = 140$. Supposing that half this number requires elevated batteries, and that the guns are separated (as recommended by the Crimean Board), 27 feet, the working party required would amount to nearly 1,500 men. One approach from each battery, as cover for a guard, and for communication, would most likely be needed; taking these at 1,000 yards for the elevated batteries, 500 men would be required. For the second main line of approach (assumed at 3,000 yards), 1,500 men would be needed, making in all a working party on the second night of 3,500 Infantry.

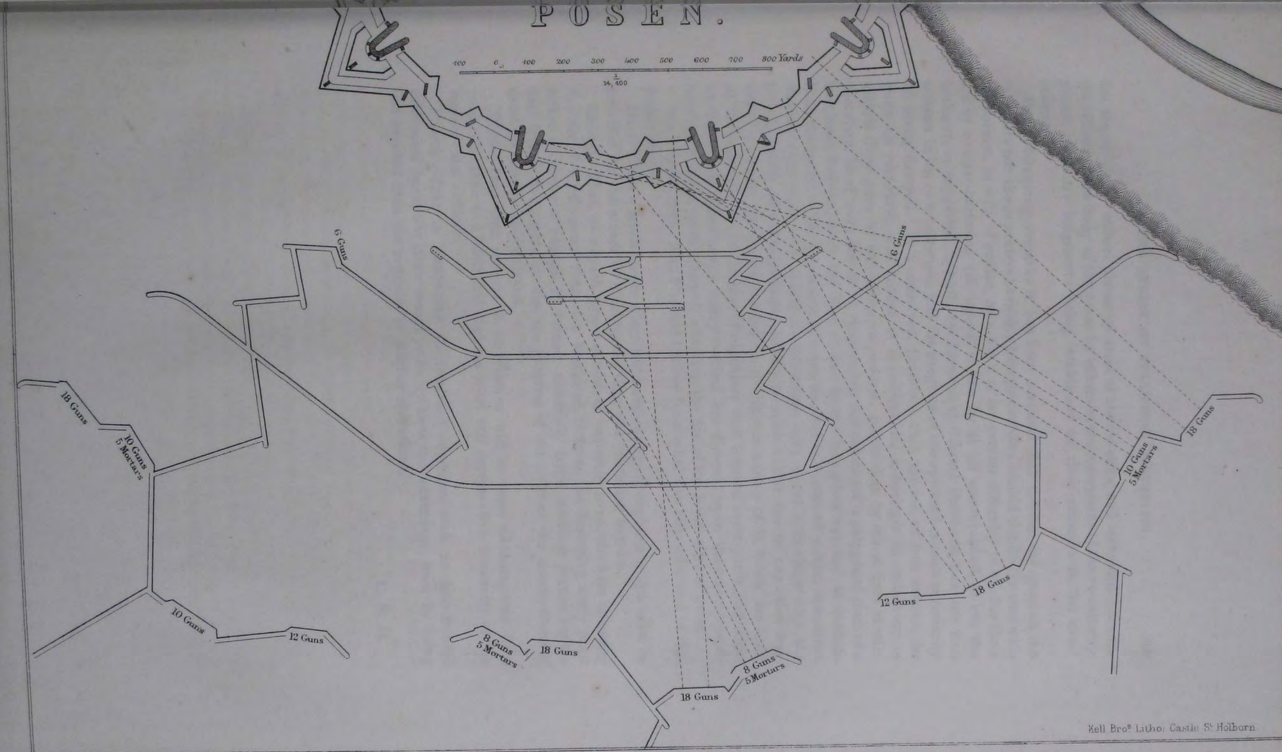
As it is not considered probable that a larger working party than the above would be procurable on any one night, it is not proposed to commence the sunken batteries till the fourth night, but on the third night to continue the elevated, commence a third line of approach, and employ the 500 men from the communications to the batteries, on traverses and magazines; on the fourth night the sunken batteries, their magazines, traverses, and communications, might be commenced, and, perhaps, together with the elevated ones, completed in sufficient time to allow of fire being opened on the morning of the fifth night.

On the fifth and sixth nights the batteries for counter-battering the extreme half fronts of the enceinte, and for enfilading the outer faces of the adjacent ravelins may be respectively commenced, according as they are elevated or sunken; and, on the sixth night, if the fire has been to some extent subdued, some progress might be made with the approaches in front of the first parallel. On the seventh night the fire of the place may, perhaps, be sufficiently silenced to allow of the second parallel and approaches in rear of it being executed, with the exception of the extreme flanks of the parallel; the extent of this work might amount to about 3,200 yards, requiring a working party for the first relief of 2,400 Infantry, if, as is supposed, the work can be executed by flying sap. The batteries formed on the fifth and sixth nights will open fire during the seventh night; and, if possible, on the eighth, or, at any rate, on the ninth night, the parallel may be extended on the flanks sufficiently to take up the prolongations of the ditches of the enceinte on each side of the axis of the attack; approaches between the first and second parallel being also formed on each flank. As it is proposed to form batteries in the flanks of the second parallel, for firing down the ditches against the caponiers, portions of the parallel may be so traced as to facilitate the execution of these batteries.

On the tenth night the batteries just alluded to will be commenced; they might contain six guns each; their distance from the caponiers would be about 1,000 yards, and, judging from results that have been obtained experimentally, they ought to be able, to a great extent, to silence their fire. It may be here remarked that the fronts of these caponiers, so far as they project above the terrepleins of the ravelins, can be more or less destroyed by the fire from the batteries which enfilade the faces of the ravelins.

From the second parallel it is here supposed that the attack will proceed much in the usual manner to its conclusion. The small masonry redoubts in the salients of the ravelins, and their covered ways, and in the re-entering places of arms, may, perhaps, create some delay in obtaining possession of these works; but, it is believed that they will have been more or less destroyed by the distant fire. It may be expedient to place batteries in the second or third parallel to act against those portions of the caponiers which flank the ramparts in which the main breach will be made.

Though from the fire of the batteries in the prolongation of the ditches, it is conceived that the caponiers will be very much crippled, still it will, no doubt, be necessary to open counter-batteries against them on the crest of the glacis, and the establishment of these will present no great difficulty, as it is the upper portions of the caponiers which would most impede their construction, and these will be the parts that will have suffered most already. Breaches in the body of the place will have been made from an early period of the siege by the batteries firing down the ditches of the ravelins; these can be enlarged by batteries on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Kell Bros Litho: Castle St Holborn

the crests of the salient places of arms of the ravelins, and extended towards the salient of the body of the place by others in the terrepleins of the re-entering places of arms; lodgments being established on their summits in the usual manner.

In the foregoing remarks it has been assumed that neither the guns on the ramparts nor the caponiers have any iron protection; should this be the case with the former, it will, of course, be a work of far greater difficulty to subdue their fire by counter-battering (if, indeed, it can be at all accomplished, unless the besieger, as suggested, I think, by Lieutenant Colonel Collinson, can use iron screens in his own batteries), and the progress of the approaches must necessarily be much delayed. It is conceived, therefore, that the use of iron screens, for guns on ramparts, will render it expedient for a besieger to endeavour to silence these guns by enfilading or reverse, rather than by direct fire; it will, therefore, be of more benefit in protracting the defence of a polygonal than of a bastioned fortress, from the fact of the former being less exposed to enfilade than the latter. The protection of caponiers (or in bastioned works, casemated flanks) with iron, will, doubtless, introduce very grave difficulties into the attack, and it would seem impracticable to subdue their fire in any other way than by mining operations, carried on, if the site admits of it, below the level of the main ditch. In the case of caponiers with internal court-yards, like those at Posen and elsewhere, a heavy vertical fire directed upon these court-yards might, however, go far towards silencing the fire of the lower tiers of guns.

The results, then, that I would adduce from what has been advanced in this paper, are:—

First—That a much larger siege train and supply of engineer stores must be provided for the attack of a polygonal than of a bastioned fortress.

Second—That, as a much larger extent of batteries is required for silencing the fire of a polygonal than of a bastioned fortress, the besieging army must either be powerful enough to furnish unusually large working parties for the first four or five nights, or else the progress of the siege at the commencement must be considerably delayed.

Third—That iron screens to embrasures will be more advantageous to a polygonal than to a bastioned fortress from the comparative immunity of the former from enfilade.

Fourth—That in comparing an iron-clad caponier with an iron-fronted casemated flank, the latter would probably have the advantage, from its being less exposed than the caponier to mining operations.

C. S. H.

PAPER IV.

REMARKS ON EXPENSE MAGAZINES.

By COLONEL CUNLIFFE OWEN, C.B., R.E.

[A Paper read at the Occasional Meeting on January 23rd, 1865.]

At every Engineer station, and in every part of the world, there are a certain number of standing grievances, the subject of a multitude of reports, letters and returns, estimates, drawings, and so forth, which never end but to begin again, or break out in some fresh place worse than before.

Among these incurable, hopeless questions, we find some smoky chimney. Whoever occupies the quarter, whoever is in charge of the works, this wretched chimney will smoke. Ingenious members of the department will undertake to prove that it does not, that it cannot smoke; alas, there is the ceiling to give the lie to these soothing strains, and the chimney is always in the workmen's hands.

But there are worse evils than chimneys. A chimney may be Rumfordized or Sandhamized, and, by dint of trying a number of successive chimney pots, one is found so preternaturally ugly, that though it does not cure the chimney it will satisfy the occupant, and make him almost proud of a chimney which gives so much trouble.

A powder magazine is, however, the greatest bore of all. Who does not know the powder magazine I mean, which is first leaky, then merely damp, which, when staunched, is insufficiently ventilated, which, when ventilators are opened, wants a boundary wall to cover them; which is then found dark, and when loop-holes are made they have to be built up again and a light-box substituted; then comes a man who finds out a corner where it is scarcely bomb-proof, or there is some winding passage down which a shell, which never could arrive there by any known law of projectiles, might roll, might burst, and so forth; and when all these sundry grievances are remedied to the satisfaction of one set of artillery officers, another brigade comes with new brooms and new ideas, who take us again through the long weary chapter of damp, ventilation, light, shot, shell.

This may seem an exaggeration. Well, perhaps it is; but without exaggeration here and there, such a dry subject will never be listened to.

But, seriously, it must be allowed that we have not yet arrived at a comfortable satisfactory sort of Expense Magazine, and the object of the present paper is to submit for the consideration of this meeting the general principles which should guide us in constructing them, illustrated by a few examples in which it has been endeavoured to carry out these principles.

A powder magazine cannot be too secure and cannot be too dry, and when these objects are not fully attained we must only thank those who call our attention to it, and no pains should be spared in satisfying both the Artillery and ourselves.

An Expense Magazine does not differ from other magazines merely in size, but in the mode in which it is worked.

A large store or reserve Magazine must be made capable of large receipts and issues, and with this view it must have doorways and passages of sufficient width and height to admit of the passage of the men engaged in making these receipts and issues; but an Expense Magazine is filled on service once in the twenty-four hours at most, and then the charges have to be issued from it, one by one, to the men of the gun detachments.

These men do not, and certainly ought not, to run in and out of the magazine for the charges, but should come to the door of the magazine for their cartridge, which should be delivered to them by the magazine man, that is by one man told off for the custody of the magazine in each relief and who never leaves it.

This at least was the mode in which the Expense Magazines were worked during the siege of Sebastopol, the only occasion on which I actually saw them being used. One man was told off to take charge of each magazine, and he never left it. If the magazine blew up, which was, I am happy to say, a rare occurrence in the British lines, he was blown up, and that was his share of the risk. He took off his shoes, his accoutrements, gave up his matches, and took every proper precaution to avoid risk, and then got the cartridges ready for the men who came to the entrance of the magazine for them.

I do not exactly recollect the size of the door, but it certainly did not exceed that of Pasley's field magazine, viz., 4 feet by 2 feet 2 inches in the clear, and even this small opening was reduced in size by a little traverse of sand bags built on the sill of the passage about 2 feet high, leaving the opening only 2 feet square or thereabouts, and it is submitted that the opening to an expense magazine need never be larger than this. It should be large enough for the magazine man to creep through, large enough to admit a barrel or case of powder, the extreme dimensions of which are 1 ft. 9 in. by 1 ft. 6 in., and no larger.

With an opening so small as this, the chances of risk from an enemy's shells are very much diminished.

The ordinary form of magazine involves a door 6 feet high and about 2 feet 6 inches wide, and the magazine floor is almost necessarily on the level of the terreplein. If the views here advanced are correct, the magazine can be built as shewn in Pl. II, and may be sunk well below the level of the terreplein.

There are other evident advantages in sinking the magazine. If built on the level of the terreplein, and made 7 or 8 feet high to the crown of the arch, it is clear that the masonry and earth necessary to make it bomb-proof will raise the structure beyond the general height of the parapet, and indicate to the enemy the position of the magazine; and further, if the magazine has to be built on made ground, or if the piers have to be carried down to the solid for the sake of a secure foundation, there is great economy in keeping the magazine as low as possible.

A magazine so buried need not be damp. There is always a ditch in front, even if the general level of the work in rear is not low enough to admit of draining to the rear.

All that is necessary therefore is to form a proper drain, either to the front or rear, communicating with a drain laid round the exterior of the foot of the foundations.

To prevent damp rising from the floor an invert of brick in cement may be formed between the footings.

Then as to ventilation: by leading a glazed earthenware pipe to the front or rear with a slope sufficient to prevent it from admitting water, an abundant supply of air may be admitted under the floor which will rise through openings round the edge of the floor into the magazine, and out through the little door when it is opened. A grating may be left in the door, closed by a slide on the inside, which would establish a certain circulation of air even when the door is shut. It will not do to use the same pipe for drainage and ventilation, for better not ventilate at all than ventilate with damp air.

No simpler or more efficient means of establishing a current of air exists than to make the openings at different levels; there must then, in most cases, be a current one way or the other.

Hollow spaces in the walls, hollow bricks in the arches, are expensive and of doubtful utility, except in cases in which the walls are built of non-hydraulic mortar, and when therefore the masonry requires to be cut into layers to give it a chance of drying; but the best hydraulic mortar should be used in all magazines, and then a wall of any thickness will always be dry if well rendered where it is in contact with the earth.

It has been stated by officers who have served at Malta, that in that island hollow walls are built against ground, and that where that is done the section nearest the ground is not rendered, and the interior section is dry though the exterior is damp. Of this I have no experience, but certainly in such a case, and also when air passages are made to dry the masonry, the air passing through the hollow walls must often be charged with damp and should be carefully excluded from the magazine.

The air for ventilating a magazine should, in my opinion, be brought direct from the outside through a dry channel, and, moreover, means should be provided for closing this channel in damp weather. When the air is overcharged with moisture the less of it that enters a magazine the better.

Brialmont relates, on the authority of a Belgian officer of artillery, that the powder in a magazine, hermetically sealed for two years, was found in better order at the close of that period, than in one which had been thoroughly ventilated (Brialmont III, p. 5).

The best receptacle for powder is an air-tight case, and the less air is brought in contact with powder the better. Probably, however, it would be found that if magazines were made air-tight, the barrels, floor, and other wood-work would suffer from dry rot, and the wisest course would seem to be to give the artillery means of admitting the air when dry and excluding it when damp.

On the sea coast, where the air is generally damp, it may often be useful to provide hot water pipes to warm the magazines occasionally, and this course will probably be adopted in the Breakwater Fort at Plymouth, a boiler being placed for that purpose in an adjoining cook-house. There can be no possible risk in leading hot water pipes under the floor of a magazine.

But to return to Expense Magazines, properly so called.

A secure place for the powder is not alone required in a battery. A place is wanted for the side-arms and small stores becoming every day more numerous with rifled guns, and also shelter for the gunners when not actually serving their guns.

The Russians at Sebastopol found it necessary to construct shelter of this kind in and behind their parapets, and this enabled them to remain on the ramparts under a fire which would otherwise have driven them away. Fire cannot in a siege be carried on continuously, and still in certain positions the gunners must always be ready to fire.

In many places too the Expense Magazines at Plymouth (Plate I) had to be built on a filling which is always hazardous, or the piers had to be carried down many feet to the solid. It occurred to me that it was desirable to utilize the space between the foundations, and as this is far more secure than the bomb-proof above, I have proposed to put the magazine below and use the upper story as a shelter for the men, a shell-filling room, a side-arm store, or for any other purpose that may be required.

This arrangement is shewn in Plate III. *L* is the magazine, *M* a lobby, *N* a man-hole communicating with the upper apartment by a wooden step-ladder, and over it a ring is provided by which the charges can be raised by a whip.

The men from the gun detachments need never come beyond the man-hole, and the magazine man need never leave the lobby except to go into the magazine or come up by the ladder when relieved.

Plate IV shews a variation of this arrangement, where the magazine can be reached from the terreplein of the work.

When, as is often the case, there are casemates under the terreplein a part of the casemates themselves may be appropriated as a magazine, and a part of the gunners find shelter in the bomb-proof above, a part may be almost in their barrack rooms and can reach the terreplein, without being exposed, by the ladder or by a winding stair, in a few minutes.

Plate V shews this arrangement which may indeed be varied *ad infinitum.* It may not even in all cases be necessary permanently to appropriate a special magazine in the casemates.

The man-hole in the arch almost necessarily takes a funnel shape, and the best way of closing it would perhaps be by a sort of bung, formed of a leather cushion stuffed with horse-hair and, perhaps, faced on both sides with wicker-work. A bung of this kind would be driven into its place by a slight explosion in the upper chamber and might save the magazine.

Anything like an ordinary door, with locks, hinges, and so forth, is to be avoided in an Expense Magazine near guns which are being fired. They are all very well in peace time, and in batteries from which practice is not to be carried on, but they cannot, however strong, be depended upon.

I have observed in many cases that the doors of Expense Magazines are, by the concussion of the fire of guns, driven, not in, but out. I have never heard this accounted for. Is it that the explosion forms a sudden vacuum in front of the gun, and that the air rushes from all parts to fill it and carries the door before it?

That the air does often act in this way I am certain from what I saw at the Crystal Palace in 1851. Several accidents occurred to the flat ridge-and-furrow glass roof, always close to the windward edge. The glass was lifted and sometimes turned over without breaking. It was in fact lifted into the eddy or vacuum formed in the current of air above the angle of the building by the still air inside the building, which was at its normal density. The subject is well worth further investigation.

For closing all openings to Expense Magazines or other buildings near guns, I know of nothing so good as strong wickerwork covered with leather or gutta-percha, or it might be payed over with some preparation of india-rubber to make it close and water-tight. The hinges should be leather and the fastening a copper chain and padlock.

Our magazines used to be lined with close boarding, and many remain so to this day. The object of this is, I suppose, to prevent grit falling on the barrels and floors, but it has the disadvantage of concealing the walls, of decaying under the least sign of damp, and of being very expensive in repairs.

Open battens have been generally substituted in many cases with great advantage and economy, but I have my doubts whether they are necessary. Major Delafield remarks in the United States' reports on the Fortifications in Europe, that nothing of the kind is done in continental works.

In many cases, I am sure, Expense Magazines, particularly in works for land defence, might be constructed much cheaper than we do now, if the idea of using them in peace time were quite given up. A good drain to the foundations, a brick or cement floor on concrete, a little puddle over the arch, would be all that is necessary to make a magazine perfectly efficient in war time, and far superior to the field magazines, which are all that the Engineers of Vauban's time ever contemplated.

To recapitulate.

The points I submit for consideration are as follow:—

We do not want a door to an Expense Magazine larger than will admit a barrel or case of powder, or larger than a man can creep through.

The magazine is safer by being sunk below the level of the terreplein, and can in that position be perfectly dry, light, and airy.

Ventilation is only useful when the air is dry, is mischievous when it is moist; the air should reach the magazine through perfectly dry channels.

Magazines should always be built of good hydraulic mortar.

A bomb-proof shelter for the gunners is almost as important as a magazine.

Where there are casemates under a rampart they should communicate directly with the terreplein.

Rigid wooden doors and metal fastenings should be avoided in Expense Magazines.

Wooden linings and even battening may be dispensed with.

In many cases permanent Expense Magazines may be built without special ventilation, asphalte, wooden floors, or other refinements.

In conclusion, I must express my thanks to Lieutenant Burke, R.E., for his assistance in preparing the drawings to illustrate this paper.

H. C. O.

DISCUSSION.

THE CHAIRMAN (General Sir J. F. Burgoyne).—There are some very interesting matters in this paper. One or two points have struck me in regard to powder magazines. I have long been of opinion that the practice of covering magazine doors with copper should be abandoned. I do not see any use whatever in it, or under what contingency it could prevent the doors catching fire. No one would take a light to a magazine. Another thing that I would give up in all magazines, is the little ventilators and openings. You ought to get as much dry air as you can into a magazine and bottle it up. You do not want a current of air, you want to get dry air. Doors and windows will always let in the air necessary. Then shut them up, for the less air the better. These ventilating openings that have shutters are constantly left open, and in foggy and wet days they let in all sorts of damp air, whereas the supply of air might be much more easily regulated by the doors and windows.

CAPTAIN RICH.—Ventilators, I think, are useful, and in the old magazines, though damp air is constantly coming in by them, you are forced to use them. In some old magazines where there is no ventilation, the water is constantly dripping from the wall, and your only chance to get them dry is to let in air for ventilation. I think Colonel Owen's suggestion of Expense Magazines not being used in time of peace is a very good one. It must be a very great disadvantage to have powder all over a fortress. Magazines opening with a door I have always found troubled with a little damp at the best of times, and I should say powder does deteriorate. I think it is a subject very worthy of consideration that all the Expense Magazines for the use of a fortress in time of war should not be used in time of peace. Another thing is the access to them not being near so safe as it ought to be. This is a great disadvantage. It is rather the feeling of the day to use them as store magazines, and to keep them always ready to set to work. Now it is not very likely that Plymouth, or any other place, would be attacked in such a hurry as not to give you time to fill your Expense Magazines.

CAPTAIN SIBORNE.—I merely wish to say that an Expense Magazine under a rampart is no novelty. Every Expense Magazine ought to have underground communication with the main magazine in order to protect the transport of ammunition. There are already several designs of Expense Magazines so placed and with covered communication to the main magazine.

COLONEL SIMMONS.—I have a magazine which I think is the worst magazine I ever saw in my life. It has a number of ventilators that cannot be closed. No means are provided for closing them, and the consequence is, damp air comes in and condenses in great quantities on the wall.

AN OFFICER.—Are the walls thick enough to exclude it?

COLONEL SIMMONS.—Oh, quite. The damp comes through the ventilators. I do not see the use of these ventilators for the preservation of the powder, which is stored in barrels and perfectly excluded from the agency of the external atmosphere. I think therefore it is a mistake to store powder in places of this sort. Another objectionable practice is the building of walls round magazines to protect the ventilators, which have a tendency to make the effect of an explosion much more violent than it otherwise would be. I believe, in the event of an explosion, it would be far better to have a bank of clay or screened earth round magazines; this would not be blown in large hard masses to a great distance, as would happen with an enclosure wall, and would also arrest some of the débris of the masonry or brickwork of the magazine itself.

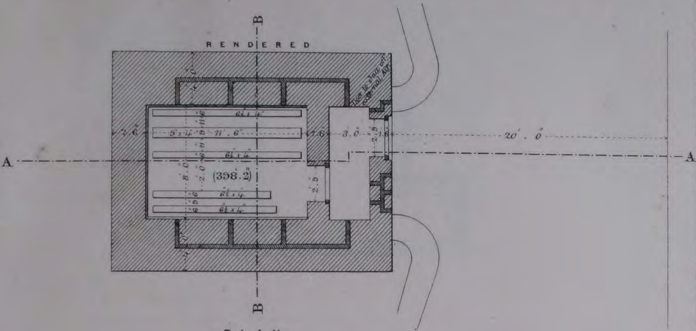
LIEUT. COLONEL GALLWEY.—We may all agree with Colonel Owen when he says that Expense Magazines should be made as compact as possible; protected from the enemy's fire; in direct communication with the magazine, and that the doors should be very small. He has given us a great many useful hints, and we must accept them. He has also given some useful illustrations, some of which, however, are capable of improvement. At the Newhaven experiments, where an earthen parapet, 25 feet thick, was fired at from a distance of 1,000 yards, some of the 7-in. shells struck the superior slope about the middle, and burst after penetrating 8 or 9 ft., clearing a gap down to the banquette. Such a shell would clear away a great part of the Expense Magazines shewn in the drawings. We must have more earth-cover now a days than formerly. I think in some of the forts the Expense Magazines are too large. At Fort Gomer they hold 50 barrels each, and are more like Auxiliary Magazines than Expense Magazines. With respect to what Colonel Owen has stated about the doors of Expense Magazines having been blown open, I may mention some personal experience while present at firing a 13-inch mortar in a casemate at Fort Elson. In the abutment or outer pier was a small Expense Magazine with a door 3 ft. 6 in. by 2 ft. 6 in., opening outwards, *i.e.* into the casemate; the door was locked. The firing of the mortar caused the door to fly violently open, which may be explained in this manner. The great and sudden compression of air in the casemate bent the door inwards and then the rebound of the door sprung the lock. The doctor of the Artillery said that it was an illustration of what happens to our ears. It so far discouraged the gunners that they did not wish to go into the casemate again, and their Commanding Officer did not choose to force them against the opinion of the doctor.

CAPTAIN FOWKE.—If it is not rather foreign to the subject of the paper, while the question of Expense Magazines is on the tapis, it might be well to say a word about the material. I know a small magazine built entirely of cement and gravel, used in the same way as in Devonshire, viz., poured in between two frames; cement concrete might be used in many cases when brick could not be afforded. Where bomb-proof cover is necessary it would be a great saving. It is also quite capable of being used where there is brick clay instead of gravel, because brick clay burnt with small coal into a kind of fine gravel makes capital cement, and can be used almost as cheaply as gravel. There are very few parts of the country where you cannot get either gravel or brick clay.

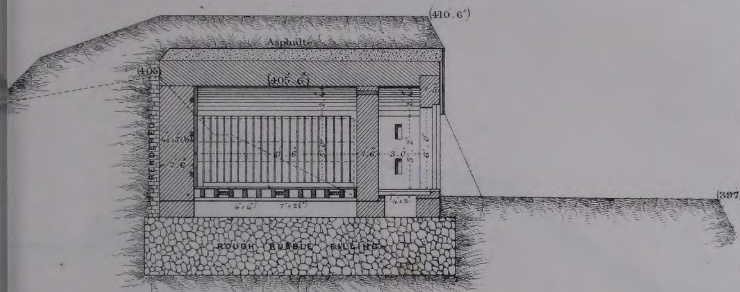
NOTE.—Colonel Owen was not present at either the reading of the paper or the discussion, but at the subsequent meeting made a few remarks in reply to what had been said.—ED.

FORM OF MAGAZINE NOW GENERALLY ADOPTED.

PLATE I



PLAN.



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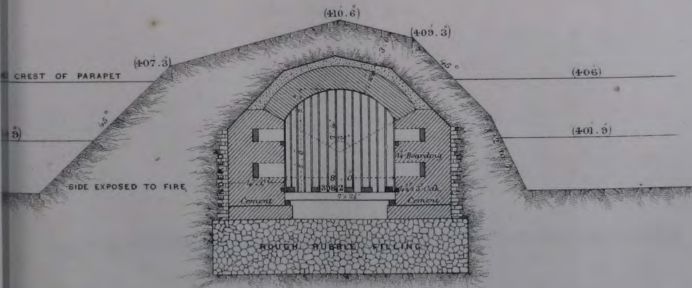

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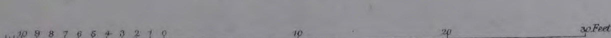
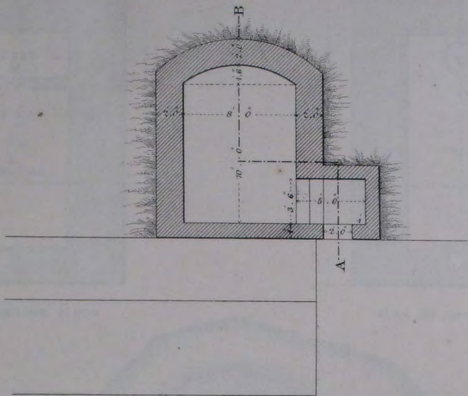
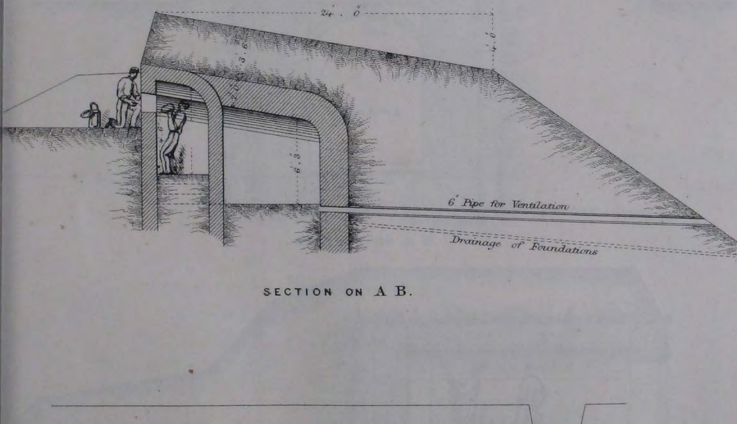


Kell Broˢ Litho, Castle Sᵗ Holborn.

PROPOSED FORM OF MAGAZINE IN A PARAPET.



PLAN.



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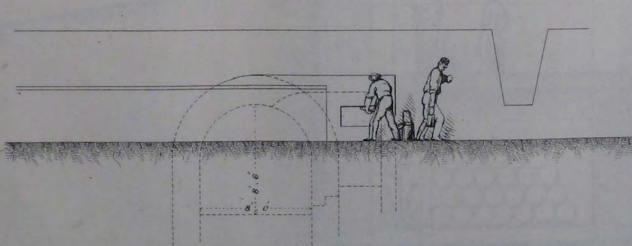


ELEVATION.

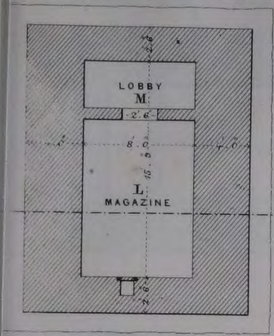
10 9 8 7 6 5 4 3 2 1 0 10 20 30 Feet

1/120

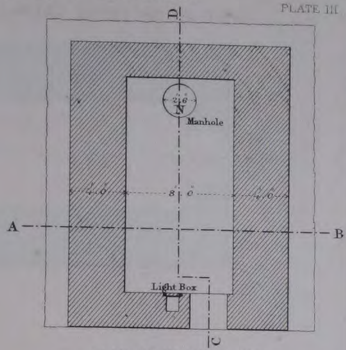
Kell Bros. Litho, Castle St. Holborn

PROPOSED FORM OF MAGAZINE IN A TRAVERSE.

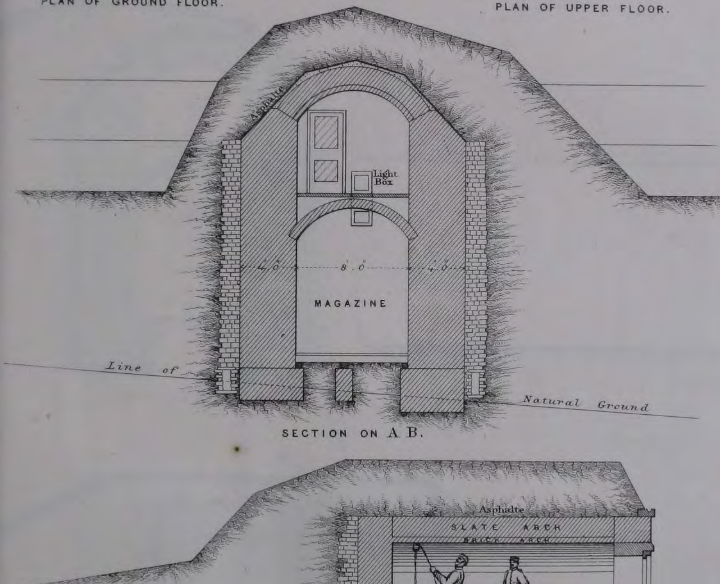
PLATE III



PLAN OF GROUND FLOOR.



PLAN OF UPPER FLOOR.



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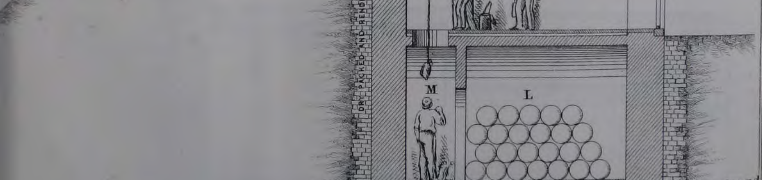

SECTION ON C D.

10 9 8 7 6 5 4 3 2 1 0 10 20 Feet

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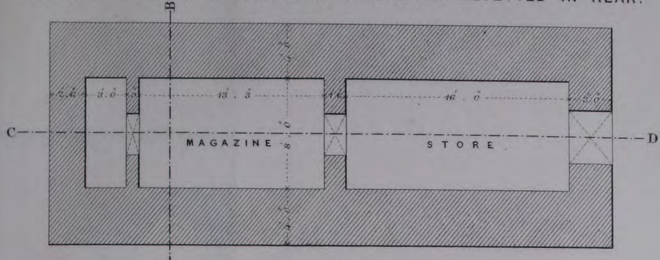
PROPOSED FORM OF MAGAZINE IN A RAMPART REVETTED IN REAR.

PLATE IV



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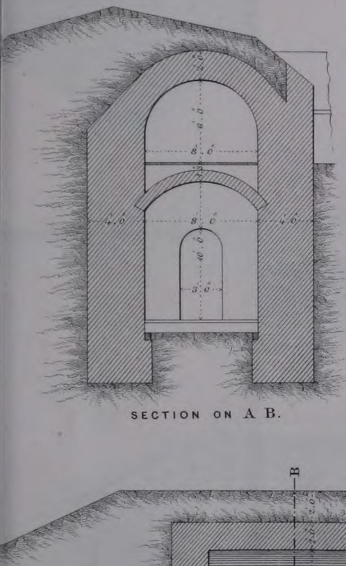

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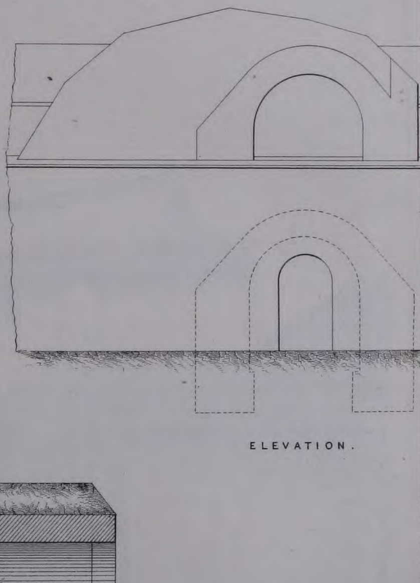
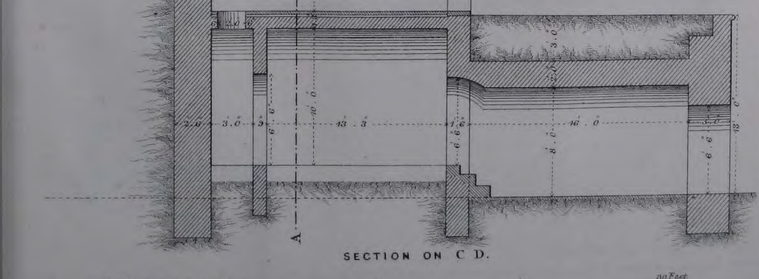
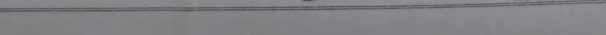


ELEVATION.



SECTION ON C D.



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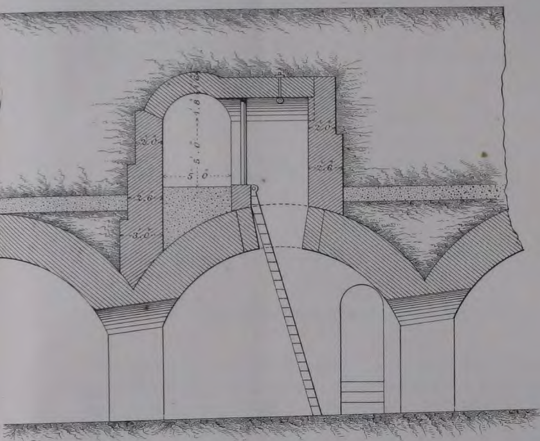
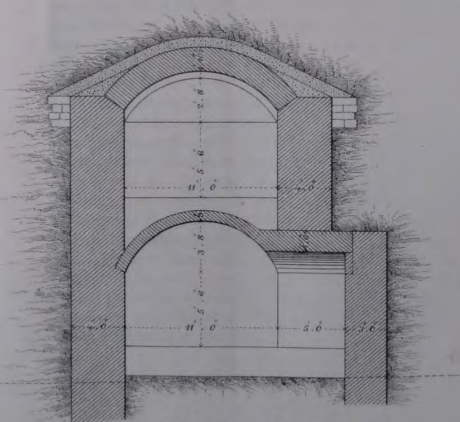
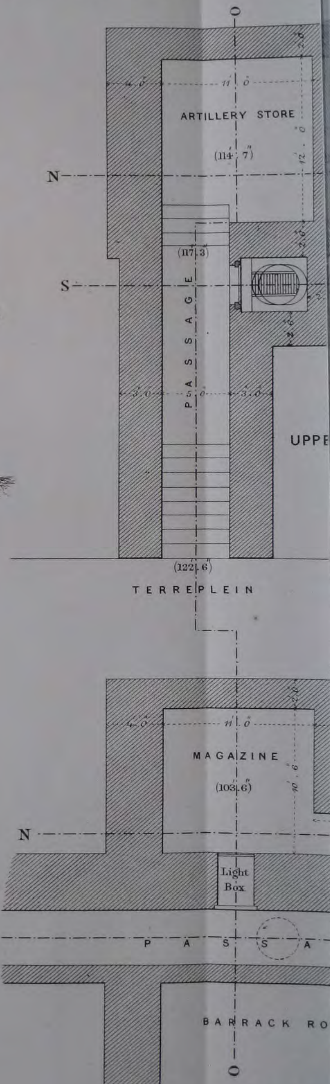
DESIGN FOR AN EXPENSE MAGAZINE



SECTION S S.

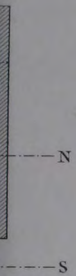


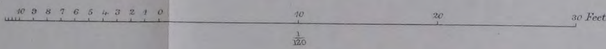
SECTION N N.



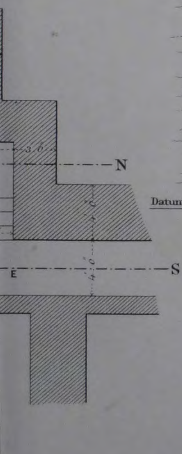
LOWER PLA

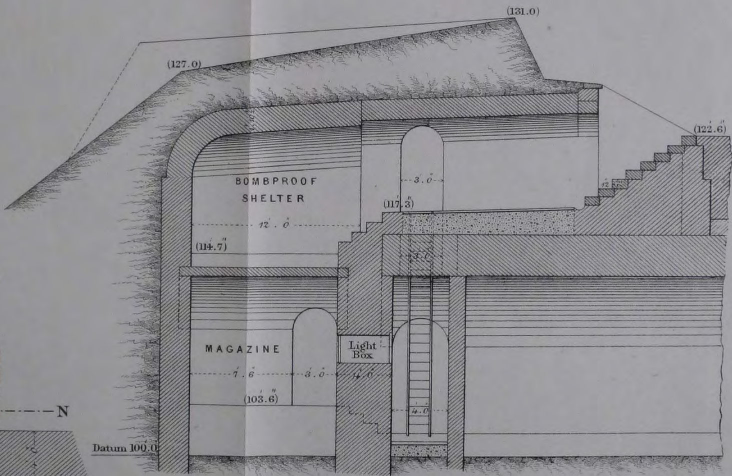
NDER A CASEMATED RAMPART.





LAN.





SECTION O O.

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PAPER V.

IRON CASEMATES.

PART I.

On the Application of Iron to Casemates.

By LIEUT. COLONEL COLLINSON, R.E.

No masonry, except of very massive character, can be expected to withstand for many hours the effect of such projectiles as those of the 300-pdr. Armstrong gun, or even of the 150-pdr. Armstrong gun. And even with the most massive masonry, the embrasures of casemates will always be weak, and liable to serious injury, if not to destruction, by comparatively few shots from such guns.

It becomes therefore necessary to consider what other materials could be employed to preserve the embrasures during a severe engagement, and possibly to replace the massive masonry walls without increasing the expense.

There are two distinct methods by which the effect of projectiles could be rendered nearly innocuous against such structures. First, by employing a material of very high elastic and tensile power, whose elasticity shall destroy the *vis viva* of the projectile, and nearly recover its original form. Secondly, by employing a material of great ductility and considerable tenacity, which by a small alteration of its form shall use up the *vis viva* of the projectile. In the first method, the material would be used in the form of comparatively thin plates of large area, without any rigid support behind, but resisting by the elasticity of its whole extent; for such a method probably the best *steel* would be the most effective material, giving the greatest power with the least thickness. A cylinder of thin steel plate gives a typical example of this method of construction. In the second method the ductile material would be used in pieces of much greater thickness, the area of which would be immaterial, because they should be supported in some rigid manner behind; for such a method probably *gun metal* would be the most effective material, having considerable tenacity and ductility. A cast-iron cylinder, thickly coated with lead, would be a typical example of this method.

But either of these materials, steel, gun metal, or lead, is too expensive at present to be used extensively in casemates: some other materials must be sought for which will contain the respective advantages of these for the above-mentioned two objects, and the expense of which will not much exceed that of the most massive masonry.

Captain Inglis, R.E., in a paper on this subject, in Vol. XI of the Corps Papers, has given a clear and complete abstract of the history of the application of cast and wrought iron to these purposes. It was quite natural that English Engineers, looking for some material that would resist the impact of shot better than stone, should turn their attention to iron, which is one of the great products of this country; and some years ago, when cast-iron was so extensively employed in civil works, in consequence of the expense of wrought iron, it was natural for them to try it for war purposes. Captain Inglis has shown in his paper that the experiments with cast-iron all proved that in its ordinary condition it is a material unfitted to resist the impact of shot, in either of the two ways above-mentioned. Its physical characteristics quite agree with these results. It has no great tenacity, little elasticity, no ductility, and though its crystalline nature gives it a high resistance to statical compression, it reduces its effective resistance to impact, because the motion of the impact is carried by means of it more rapidly through the whole mass immediately in front of the part struck, causing thereby as hearing action on the surrounding parts; and as the distance, through which particles of cast-iron can be elongated before rupture takes place, is exceedingly small, a very small motion between one part and the other of the cast-iron produces a crack; and thus a comparatively small body, if moving at high velocity, will produce a crack in cast-iron; and it was found in the experiments that even blocks 8 ft. × 2 ft. × $2\frac{1}{2}$ ft., were cracked through by 68-pdr. shot at 400 yards.

But though cast-iron in its highly crystalline hard condition is unfit for these objects, it is quite possible that if reduced to a softer and more ductile condition, although it may still have little elasticity or tenacity, it may be found so capable of resisting heavy projectiles in the second method above-mentioned, as to be quite suitable for employment in casemates. The *annealing* of cast-iron, which is at present applied only to small objects, for the purpose of making cast-iron sufficiently malleable to be used in small articles of furniture, seems to promise a mode of effecting a modification in the structure of it, which may make it fit for the purposes under consideration.

The great use of wrought iron in railways and civil constructions during the last 30 years, has produced such improvements in its manufacture and reduction in its cost, that it can now be made of such large dimensions and so cheaply as to allow of its being used in some parts of fortification structures, in competition with stone. And a considerable further impetus has been given to improvements in its quality and dimensions by the use of it for large ordnance and for coating vessels of war; the labours of the Iron Plate Committee of 1861-3, certainly tended very much to raise the quality and size, and decrease the cost, of wrought iron for war purposes. So that there is a prospect of its becoming still more available in qualifications and cost for fortifications. Its peculiar merits for these purposes are its ductility, elasticity, and tenacity combined; also the comparative facility with which it can be worked on the spot into the shape required, and connected together. These qualifications render it suitable for employment in both the above methods of resisting the impact of projectiles.

The following are the different general modes in which such a material can be applied in the construction of casemates.

1*st. In Solid Plates.*—In this mode, of which the sketch *(A)* represents a general type, the wrought iron is rolled into rectangular plates, which are supported in their position as the front wall of a casemated battery, by wrought iron frames or standards placed at right angles to them, and as nearly immoveable as practicable, and to which the plates are connected by bolts. A projectile striking the centre of the plate, deflects it in the form of a bulge, larger or smaller than the diameter of the projectile according to the velocity of impact; and supposing the projectile to be stopped by the plate, the work done by it after impact will have been the deflection of the plate to that extent, the punching of an indentation of the size of the projectile, and the elongation of the bolts of the sides, by the reaction of the two frames behind, supposing them to remain uninjured. This work corresponds nearly to the work which would be done on a plate by a statical pressure deflecting it to the same extent, and a statical pressure punching the same indentation. The effects in each case are not precisely the same, because the area of deflection made by the projectile varies with the velocity, and becomes very small with very high velocities. With comparatively low velocities the punching action would nearly disappear, and the whole plate would be deflected; with high velocities, almost the whole action would be one of punching. Without some further experiments on the effect of velocity with respect to this question of the area of deflection, it is impossible to form any satisfactory calculations of the effect of projectiles; it is only by assuming that the whole plate is deflected that an approximate comparison with the statical force to produce the same result can be made. Now the statical force to produce the same deflection in a plate so situated up to the point of rupture varies *directly* as the *length*, *breadth*, and *thickness* of the plate, and *directly* as a fraction composed of the *square of the tenacity* divided by the *modulus of elasticity*. Hence to resist low velocities and large projectiles, there is an advantage in using SQUARE PLATES, of very high tenacity; because, with long plates, although the total work expended may be the same, the actual amount of deflection is much greater (increasing as the cube of the length), and therefore there is a greater liability to crack the beam in any imperfect part.

With high velocities, when almost the whole action of the projectile is expended in punching a hole little larger than itself in the plate, an approximate comparison may be made with the statical force required to produce the same indentation. Now, the statical force to punch a given hole in a given plate, varies *directly* with the area of the shearing section and with the shearing strength of the material; and as the shearing strength is nearly identical with the tenacity, the statical force varies *directly* with the *diameter of hole, thickness of plate,* and *tenacity.* And the mechanical effect of the punching is equal to the statical force multiplied by half the depth of indentation; if the hole is punched through, that indentation amounts, with flat-headed plungers, to half the thickness of the plate, and, with hemispherical headed plungers, to nearly the thickness of the plate. Hence the whole mechanical effect expended on the punching varies *directly* with the *diameter of the hole*, and with the *square of the thickness* of plate, and with the *tenacity*. Therefore to resist high velocities there is a great advantage in using thick plates of considerable tenacity; and an advantage to the attacker in using elongated projectiles.

Therefore, as far as thickness is concerned, *a given plate requires a greater expenditure of dynamic force to punch a hole in it, than to break it by deflection.* Further, whereas an increase of thickness is a great advantage to resist punching, it is not so great an advantage to resist deflection, because the rupture-deflection of a plate varies *inversely* with the cube of the thickness.

2nd. In Bars.—In this mode, the iron is rolled into bars, the width of which is not greater than their thickness; they are laid horizontally or vertically side by side, and should be connected together as firmly as practicable, either by bolts or by the form of their cross sections. The sketch *(B)* shows two descriptions of bars, which are typical representations of this mode of using iron. They require the same rigid frameworks fixed at right angles to the back of them at intervals, as with the plates; but they must be connected with them, either by large bolts passing vertically through the bars and connected above and below with the frame-work; or by dovetailed tenons at the back of the bars, fitting into similar mortices in a solid upright forming part of the frame-work. Other modes of fastening might be used, the above two are the most typical.

The action of the impact of a projectile deflects the bars it strikes, and with them the neighbouring bars. It approximates to the case of a plate, more or less according to the completeness of the connections of the bars; but there is always this difference between the deflections of a plate and an assemblage of bars, that, however close the connection, there is sufficient time before one bar moves the next one, for each single bar to take up the motion of deflection independently, and the reaction from its striking the next bar (though the space and time are so exceedingly small) is sufficient to assist in driving the ends of the bar, first struck *backwards* in the direction the projectile came from, and thus assist the deflection of it. Now if the dynamic force to deflect a bar varies directly with the *length* and *breadth*, a comparatively narrow bar will be broken by the deflection rather than by the punching action. Judging by theoretical calculations, it requires a much less dynamic force to break a beam by deflection than by punching; therefore there is always a greater tendency in an assemblage of bars, than in a solid plate, to crack by deflection.

It is difficult to conceive any description of connection between the bars that would long withstand the concussion of projectiles, and yet be effective in the way of transmitting the motion from one bar to the other. That shewn in the upper part of the sketch has been very carefully carried out in Hughes's Cronstadt shield; but supposing that the projecting tenon part is strong enough to withstand the shearing strain it would be exposed to, the shape of it would cause a resultant action in a vertical direction upwards and downwards, which would loosen the connection at each blow.

The **I** form of cross section of bar shewn in the lower part of the sketch, is open to the same objection of the independent action of the bars, and to the still further objection that the reaction of the neighbouring bars has a different effect on the different parts of the bar struck, which causes a shearing action at the angles of the **I** cross section. If the tenon shown in the other form of bar does not withstand the shearing action (and it has been found by experiment to be a weak part in this plan of shield), it cannot be expected that a bar made up of tenon and mortice as the **I** is, would remain long uninjured.

In the punching action, that is when the velocity of the projectile is so great, that a considerable part of its force is expended in punching an indentation in the bars, if the hole punched is not larger than the breadth of a bar, then the resistance of the upper form of bars would be as great as that of a plate of equal thickness: if the hole is larger than one bar, there is not the same amount of friction to be overcome in driving out the plug in front of the projectile, as in a plate, and consequently the resistance to punching will be less. In the lower form of bar, the resistance to punching will approximate to that of a series of thin plates, which is as the sum of the squares of their thicknesses, instead of as the square of the whole thickness. Consequently in both cases the resistance to punching will probably be less than that of a solid plate. In general, however, a wall of bars is more likely to be broken by deflection than by punching.

The fastenings and connections of the bars with the frame-work behind are subject to greater strains than the bolts of solid plates. Owing to the vertical action before mentioned, and to the reaction of the ends of the bars, which will be much more lively than in a solid plate, the vertical bolts or tenons behind, or whatever fastening is used, will be exposed to both tensile and shearing strains. It has been found by experiment, that with this plan of using iron the fastenings are the most difficult part of the question.

3rd. Thin Plates flat.—In this mode of using iron, several thin plates of considerable area are joined together to obtain the requisite thickness to resist penetration, and are connected with some description of frame-work behind, by bolts passing through all the plates (see fig. *C*). This method therefore is similar to that of solid plates, as far as the mode of fixing is concerned; the difference between them consists in the comparative resistance to projectiles offered by a solid plate of given area, and by an assemblage of thin plates of the same area, fixed close to each other and making up together the same thickness as the solid plate. The resistance to deflection of the assemblage of thin plates is probably *greater* than that of the solid plate: for the dynamic force to deflect them to the point of rupture, varies *directly* with the *length*, *breadth*, and *sum of thicknesses* of the several plates, and is therefore the same as that of the solid plate; but the *extent* of rupture-deflection being directly as the cube of the length and inversely as the cube of the depth, the rupture deflection of the thin plates will be more than that of the solid plate (being inversely as the sum of the cubes of the respective thicknesses of the thin plates), and consequently there will be more time for the whole of the particles in the thin plates to take up the motion.

But the resistance to the punching action of the layers of thin plates is *much less* than that of the solid plate; it is the difference between the sum of the squares of the thicknesses of the thin plates and the square of the thickness of the solid plate.

Consequently, for resistance to projectiles of large diameter and low velocities, an assemblage of thin plates has some advantage over a solid plate of the same thickness. But for resistance to projectiles of small diameter (that is to say elongated) and high velocities, a solid plate has great advantage over an assemblage of thin plates, which advantage increases with the total thickness employed. The experience in the United States, from which they have adopted the use of layers of thin plates for their vessels of war, appears to confirm this theory, because their guns, from which the experience has been obtained, in general throw projectiles of large diameter with lower velocities than those common in our service.

4th. Thin Plates edgeways.—In this method the iron is rolled into thin plates which are cut into strips of a breadth equal to the total thickness of the wall or front required, and these thin strips are laid over each other in horizontal laminæ, and are fastened together, either by bolts passing vertically through them from top to bottom, or by some other method connecting the several laminæ firmly together, and with some immoveable frame-work behind, (see fig. *D*).

For resistance to deflection, it is evident that this is an inferior form of the "bar" method; for even supposing that the connection of the laminæ together is exceedingly efficient, three or four such laminæ do not present as much resistance to deflection as a solid bar of the same width and thickness. Each individual lamina will be more or less in the condition of an isolated bar of small width, and great depth or thickness, presenting a comparatively slight resistance to deflection, and the inner edge of which will be broken by a small deflection (the rupture deflection being *inversely* as the cube of the depth or thickness).

For resistance to the punching action, these laminated plates do not present so much as bars of greater width; because the area of the indentation is certain to extend over several laminæ, and the friction of punching a hole through an assemblage of such plates edgeways will not be so great *theoretically* as in a solid bar or plate.

Thus it appears that neither in the deflective action nor the punching action do the laminated plates present so great a resistance to projectiles as bars or solid plates. They have however advantages practically: that very weakness to resist the punching action makes them more effective and economical than almost any other form, for the fronts of casemated batteries. It makes it almost certain that the action of the projectile will be expended in punching and not in deflection; by separating the laminæ slightly that action might, if necessary, be reduced to a certainty. But to punch a hole in a given plate requires a greater dynamic force than to break it by deflection; in other words, to resist a given projectile will require a plate of less thickness for punching than for deflection. Then, in the punching action, the injury is confined to the spot pierced; it does not weaken the whole structure as does rupture by deflection; therefore a given front will resist a greater number of projectiles in the former way than in the latter. It is desirable to have iron of a high tenacity to resist punching, but a high elasticity is not necessary, on the contrary, ductility is advantageous, because then the impact crushes the laminæ together into one mass. Hence a cheaper description of iron could be used and therefore a greater thickness of it, which gives a further advantage towards resisting punching.

On the whole, this method of laminated plates appears to be the most practically effective and economical of any, for the fronts of casemated batteries.

Roofs.—It is intended to consider in this section only those roofs which are composed entirely or chiefly of iron.

As regards resistance to impact of projectiles, the roofs of casemated batteries may be divided into two classes:

1st. Those covered with earth or concrete of sufficient thickness to absorb the whole force of the projectile.

2nd. Those resisting chiefly by the elastic force of the iron.

1st *Earth or concrete covered.* (see fig. *E*).—In this form the thick coating of earth or concrete is supported by some kind of frame-work of iron, generally of iron beams at intervals, the spaces between which are filled in with wooden beams, with iron plates, or with brick arches. A similar construction in fact, though stronger, to a fire-proof floor. Supposing a projectile to fall upon this roof vertically and penetrate to a certain distance *(A B)* before coming to rest, then the dynamic force expended would have been equal to the *resistance* of the material to penetration, multiplied by half the distance penetrated. By equating this with the dynamic force contained in the projectile at the moment of impact, a value for this *resistance* can be obtained, which represents the additional statical pressure imposed upon the roof during the progress of the projectile from *A* to *B*. The frame-work and filling in which support the covering must be calculated to bear this statical weight in addition to the dead weight. If the projectile strikes in the centre between two main beams, this statical pressure may be considered as spreading from the point of contact on all sides in the form of a cone, and the area of the base of that cone on the beams or plates below, will give the area of distribution of the pressure; this area will depend on the nature of the material of the covering. It will be safer in general to consider it as pressing on the centre between two main beams.

There will be an immediate deflection of the roof-beams on the sudden accession of this additional pressure, and there will also be a vibration throughout the whole roof; for these reasons it is desirable that the whole roof should possess some elasticity, and that all its parts should be well connected together. And hence it is disadvantageous to use brick arches in connection with iron beams; because the elasticity of the one and the stiffness of the other will tend to break the brick arch. This objection does not apply to the use of wood; if an arrangement of that material can be made strong enough, and if it is covered on all sides with concrete so as to preserve it from decay, it may be used to fill in the spaces between the main beams, in a manner similar to that employed for some fire-proof floors. For the same reason there is an advantage when thin plates are used, in giving them a camber or convexity upwards.

2*nd. Solid Plate.*—If a roof be formed of iron alone without other covering material, it is in the condition of the iron front of a casemate laid horizontally, and subject to rupture by deflection and punching, by projectiles striking perpendicularly to its surface. It is therefore subject to all the considerations applied to those fronts, and might be constructed in either of the methods above described, according to the projectiles it is required to resist. But in general the projectiles that would fall on a roof are spherical and hollow, having comparatively low velocities, and consequently their action against any opposing surface would be rather one of deflection than of punching. The form therefore of solid plates of large area is more suitable for roofs than any arrangement of laminated plates, more especially because the solid plates would form a lighter roof and be more easily supported.

A flat roof of solid plates could be constructed that would resist ordinary projectiles; but as it is easy to support almost any amount of vertical force arising from a roof, and as a series of contiguous casemates gives mutual resistance to any horizontal thrust from the roof, it is therefore advantageous to employ the iron plate in the form of an arch.

The effect of a projectile falling vertically on the crown of a curved solid plate, would be to deflect it somewhat in the form shewn in the fig. *(F)*; and the resistance of the plate would be compounded of the force necessary to turn over the parts of the plate *BD* and *MN* about the points *D* and *N*, together with the moments of inertia of the cross sections of the plate at *D*, *B*, *A*, *M*, and *N*. Now supposing the projectile to fall on the crown of the arch, vertically, the force acting to turn over the parts *BD* and *MN*, is the horizontal force due to the motion of the plate about the point *B* acting at the points *B* and *M*, with the leverage *FD*. And that horizontal force is equal to the moment of the vertical pressure at the crown about *B*, divided by the height of the crown above *B*. And the vertical pressure at the crown is made up of the actual weight of that part of the plate *MAB*, together with the resistance of the plate to deflection, which resistance is obtained from the equation, that the dynamic force contained in the projectile at impact is equal to that resistance multiplied by half the deflection *AL*.

The point *B*, at which rupture would be likely to take place, would be the point at which the horizontal force of the arch is greatest.

There would also be a certain amount of the punching action take place, from the impact of the projectile, the resistance to which would be calculated similarly to that for any other plate.

By working out the above general expression for the work done in deflecting a curved plate in that manner, it will appear that the dynamic force required to break such a plate varies *directly* according to two terms, one as the *thickness*, *breadth, and span of the curve*, and the other as the *square of the span*.

Consequently when curved plates are used for roofs of casemates, there is an advantage in connecting them together as much as possible to form one continuous plate in one continuous curve over the whole gun chamber to be covered. But though a thin plate of larger area might require the same expenditure of dynamic force to break it by deflection as a thick plate of less area, it would be more liable to rupture by punching: this last consideration will therefore to some extent determine the thickness of the plate, and consequently its minimum area to resist deflection by a given projectile. A comparatively thin plate will break a cast-iron shell on impact, and therefore as long as the roof has only to resist cast-iron shells, it will probably be advantageous to make it in one continuous plate; if additional strength is required to resist the punching action, it will probably be most advantageous to obtain it by curved ribs of wrought iron of a deep and narrow section, and fastened to the curved plate on the underside at such intervals that a shell could not penetrate between two of them.

Bolts.—If any beam is held by two bolts at its ends, and deflected by a pressure in the centre, the moment of resistance of the two bolts must be exactly equal to the moment of the pressure *minus* what may be due to friction at the points of support. That is to say (leaving the friction out of consideration) the tensile strength of the bolt at *A*, multiplied by *AB*, must be equal to half the pressure at *C*, multiplied by its leverage *BC*, (see fig. *G*). Or if it is a projectile striking at C, and deflecting the beam to its breaking point, then half the work done by the projectile on the beam, that is to say half the equivalent statical pressure multiplied by half the amount of deflection, must be equal to the modulus of elasticity of the bolt, multiplied by its area of cross section, and multiplied by that proportion of its length to which it must be extended to cause rupture. And as the amount of extension of the bolt is to the deflection, as AB to BC, the length of the bolt must be varied directly in that proportion, and consequently the area of the bolt will be decreased in the same proportion.

If the beam is a broad plate, and fastened by several bolts at each end, and struck exactly in the centre, then the bolts will have to bear proportions of the whole strain respectively, as half the length of the plate divided by their respective distances from the bolts opposite the centre; so that each bolt should be calculated to bear the whole strain *less* that proportion borne by the others. The longer a bolt is the better, to resist such strains caused by impact; but it would not be safe in all cases to reduce the area in proportion to the length. A bolt should be the same thickness throughout, otherwise, in the act of the elongation, a sudden increase of strain is brought upon the narrow part, causing it to yield more than the thick part, and it will be very liable to break at that point. With bolts with screw heads, the thickness of bolt calculated must be that of the inner diameter of the screw head. The dimensions of screw heads and nuts may be calculated by the same rules as for statical pressure, allowing a more liberal coefficient, and a thick washer of some very malleable material should be placed at each end.

The reports, by Capt. Inglis, in Vols. XI, XII, and XIII, Corps Papers, of the experiments at Shoeburyness, give nearly all the practical information that has as yet been obtained on this subject.

With respect to the number of bolts for a given area of beam or plate; or (which is nearly the same thing), with respect to the maximum size of any one bolt, the only theoretical limit appears to be that the area of the sections of the plate about any one bolt, namely, of $ab + df$ or of $ac + de$, shall be sufficient to resist the shearing strain on those sections caused by the strain on that particular bolt. Therefore the larger the bolt the further it should be from the edge. There should be at least four bolts to every separate plate, one near each angle.

Rivets.—The calculation of the arrangement and dimensions of rivets used in casemate works, is subject to the same considerations as for those in ordinary constructions to resist statical weight. Some of the rivets are subject to shearing strains arising from compression, and some from tension. Theoretically the former should be of large diameter, and the latter as small as practicable; but practically in dealing with projectiles, it is only necessary to take care that the whole number of rivets connecting any two pieces of plate-iron, shall be of sufficient strength together to resist the shearing action arising from the impact of the heaviest shot that can strike the part, allowing a larger coefficient than in ordinary civil works. Because part of the principle of using plate-iron fastened with a great number of small rivets, is that the rivets over a part of the plates may be destroyed without materially injuring the connection of the plates. This is one of the great advantages of the system of thin plates and small rivets over that of thick plates and large bolts.

Backing.—Theoretically, no soft or elastic backing is of much assistance to the main plating, unless the material of the backing is nearly equal in strength to that of the plating. When the material of the backing is much inferior in strength, the plating is penetrated by punching or deflection before the whole mass of the backing is affected. Such backing may nevertheless assist in the general resistance of the front of the casemate; it may be sufficient to destroy the force remaining in the projectile, after having its velocity greatly reduced by passing through the armour plating, especially if it is enclosed in a casing of thin plate, such as is sometimes called the *skin*. The backing of wood, which has generally been used for ships, has other advantages for naval purposes, besides that of assisting in the general resistance: it is buoyant for its strength, elastic, easily repaired, and its injuries are generally local. Its liability to decay, and its want of strength are two great objections to its use in permanent land defences. It may however be used to advantage as a backing between iron and stone or brickwork, for then its elasticity allows the full force of the iron to be brought into play, and distributes that pressure over a larger area of the masonry; in such cases, as the wood is intended to act only as a kind of cushion, the mode of fixing it is not important, nor would its destruction affect the general security of the casemate.

Any backing having somewhat the same degree and character of elasticity as wood, is open to the same considerations and objections, and none therefore are of much value in permanent defences, except as cushions between two hard materials.

A backing of comparatively hard material, or of a construction so rigid as to be nearly the same as that of the plate itself, assists the general resistance, both by the immediate reaction of its mass, and by its resistance to penetration. A compound backing, such as that of Mr. Chalmers, adds to the resistance of the plating to deflection, nearly as much effect as the work required to be done to break it by deflection. The frames or piers of plate and angle iron, which are generally proposed for the main supports of the thick plating in casemate fronts, assist chiefly by the resistance of the web or thin part to crushing or buckling; much of their efficacy depends therefore on the way in which the web is strengthened.

Under this head may be properly mentioned a mode of combining the plate-iron and concrete in cases for piers, &c., of casemates, which has been suggested by Captain Cornes, Captain Inglis and Lieutenant Colonel Scott, R.E. (see Chatham Papers No. 19, Vol. I; No. 8, Vol. III; and Corps Papers, Vol. XI).

The general description of this method is that the pier or wall is constructed of thin plate-iron and hollow, and afterwards filled in with concrete. Considering the very slight additional resistance afforded by plate iron 1 inch thick, and that this form of pier is very liable to be *punched* by projectiles, it appears probable that this mode of construction will gain very little in point of dimensions over the pier of solid masonry. And considering the observed penetrations in concrete of 24-pdrs. at Woolwich and West Point, it seems probable that a pier of this kind, nowhere less than 6 feet through, will be a sufficient resistance to siege guns. This does not however express the full advantage of these hollow piers filled with concrete. The plate iron connects it altogether so effectually that the concrete must be riddled with shot and broken into fragments before there is danger of the whole falling, so that it might still form a support to a bomb-proof roof, although a passage for shot was opened through it into the casemates. As Captain Inglis says, it would be difficult to form an effective breach through such piers. Probably the most effective mode of constructing such piers and walls, is according to that recommended for masonry casemates, namely, to consider the whole front of the casemate as a wall 6 or 8 feet thick, and to cut out of it the embrasures for the guns, from which the forms of the piers and roof of embrasures will be obtained; the thin plate-iron can then be arranged to enclose the area of the piers so formed, those exterior parts near the embrasure, where the pier is thinner, being strengthened with thicker iron. In order to add to the weight of the mass, it is desirable to connect the piers with the roof and floor.

General Remarks on the best form of using Wrought Iron in Fortifications.

The first principle that we may deduce from the foregoing considerations and from the experiments that have been made, is that in applying wrought iron to fortifications it should be treated simply as so much material, having particular characteristics of strength, &c., and should be applied to whatever parts of the works those characteristics are specially suited for, precisely as any other special material would be. There is no reason why wrought iron should be considered as only applicable to the fronts of casemated batteries, or why it should be necessary to work it into some special elaborate form before applying it; it is a material having great strength and elasticity, and is applicable to all parts of casemates where those qualities are required; and, as in all other materials, the simpler the forms, and the simpler the mode of application, the better.

The forms and mode of application ought to be simple, in iron especially, because it is expensive and difficult to work it in large masses. To do any work on such large pieces of iron as have been used in the shields experimented on at Shoeburyness, requires large fires and heavy machinery, and for this reason alone large masses and elaborate forms are to be avoided. It is a long operation to drill holes in thick iron, or to cut off a piece of it, or to plane it, or to alter its form even slightly; therefore the use of such large masses should be avoided, as are of special elaborate forms to fit special places and require nice fitting, are liable to be made partly useless by blows from a projectile, and are not easily repaired even when time and means are available.

Iron should be used in not too large pieces so as to become unwieldy of movement; in forms such as are ordinarily procurable in the market, and such as will require as little additional work upon them as possible to prepare and fix them in their places; because iron cannot, like wood and stone, be readily altered on the spot to suit special wants. The simple and ordinary forms have the further advantage that the structure will be more easily repairable after damage.

The next point is the various uses to which it is likely to be applied. It may be used for the fronts of casemated batteries against all sorts of fire-arms; in some caponiers, against musketry; in others against siege guns, such as the smooth-bore 24-pdr. or the rifled 40-pdr.; in sea batteries against 150-pdrs., and in some cases against 300-pdrs. It may also be properly used in roofs of casemates, either to carry a superincumbent load of earth or concrete, or as a bomb-proof in itself. Also, in protecting the embrasures of existing masonry casemates; and in covering particular parts of existing masonry escarps. In all cases in which it is used for fronts, it is desirable that the form and size of pieces should be applicable to any kind of front, and that a front should be capable of being easily strengthened or repaired.

Though wrought iron is applicable to these parts of casemates, it does not follow that it would be preferable to all other materials. It must be compared in each case with the ordinary materials that would otherwise be used, on the three points of efficiency, durability, and economy.

When a defence against musketry only is required, the experiments which have been recorded from time to time in the Corps Papers, shew that a plate of good wrought iron *one quarter of an inch thick* is proof against any existing *musket* or rifle with a lead ball. And the experiments recorded by Captain Inglis in Vol. XI show that a plate *one inch thick* is proof against any *wall-piece* that is likely to be used in warfare; that a plate *two inches thick* is proof against ordinary *field artillery* such as the 12-pdr. Armstrong; and that a plate *three inches thick* is proof against ordinary *siege artillery* such as the 40-pdr. Armstrong. All without any backing behind the surface of the plates.

Up to this point of defence—that of resisting siege artillery—it appears probable, from theoretical as well as practical considerations, that the most efficient form in which wrought iron can be used for fronts of casemated batteries, is in LARGE SQUARE PLATES, and the larger the area of plate the better. As the extreme size of a front of a casemated battery for land defences is not likely to exceed 12 feet long by 8 feet high, and a 3-inch plate of those dimensions can now be rolled at a price not much, if at all, above that of ordinary rolled iron, and will not weigh more than 5 tons; it would appear desirable in many such cases to use plates of the full dimensions of the front, and to have the embrasure and the bolt holes cut in it before it leaves the manufactory. A plate of this description will admit of being strengthened by supports and backing of thin plates, framed together somewhat in the manner of the cellular backing proposed by Mr. Chalmers, which strengthening can be increased to almost any extent. Therefore in using these large plates of 3 inches thick, provision can afterwards be made for increasing their strength to meet any small improvement in siege artillery. No backing beyond the supports necessary for fixing it securely in its place would be required for resisting existing siege guns.

The same form and thickness of plate appear most suitable for protecting existing escarps against ordinary siege guns; and also for protecting the embrasures of existing masonry casemates against such guns. But in these cases, as in all cases where wrought iron is placed in front of masonry, it is desirable to have a backing of some material like wood between it and the masonry, sufficiently thick to allow the iron to be deflected to its full extent before touching the masonry, and so distribute the effect of the blow over a greater area of the masonry; otherwise the strongest masonry will soon be shattered by the concussion of the hard iron plate on it. The bolts or fastenings connecting the plates with the masonry, should in all cases go through the extreme thickness of it, that is in the case of an escarp, to the rear of the counterforts, and be secured there with large washer plates, and some slightly elastic material between the washer and the masonry; because the object of the iron plates is not so much to prevent a projectile entering into the masonry, as to prevent the latter from falling so as to form a breach, when injured by projectiles.

For the fronts of sea batteries to resist 150-pdrs. (Armstrong) and 300-pdrs. (Armstrong), the most effective form of using wrought iron, as far as experiment proves, is in that proposed by Captain Inglis in Vols. XI and XII, Corps Papers, namely, in PLANKS of 18 *inches and* 24 *inches wide, and* 6 *to* 8 *inches thick*, in two thicknesses; the planks in one are at right angles to those in the other, forming together a front at least 12 inches thick (not including the frame-work behind). These planks may be of rolled iron, cut at the manufactory into lengths to suit the purposes required of them, that is to say in two lengths of about 12 and 8 feet respectively, and with the proper bolt-holes drilled in them. Such planks can now be obtained in the market at about double the price of ordinary rolled iron (though this price will probably decrease), and as the heaviest piece will weigh little more than 2½ tons, they will not be too unwieldy for this special object.

A shield constructed of two thicknesses of such planks is the only one which has effectually resisted a 300-pdr. Armstrong gun.

Such planks would, as Captain Inglis suggests, be also applicable to the protection of existing walls and embrasures of masonry sea forts. For such purposes, however, only one thickness of plank would probably be necessary, and in these cases a backing of timber should be placed between the iron and the masonry, for the reason before given. These planks would require no further work to be done upon them on the spot, beyond the labour of putting them in their places; the only work to be done on iron on the spot, would be on the thin plates for the frame-work behind, and on the bolts. Consequently a supply of such planks could be kept in a sea fortress, and could be fitted to any casemates requiring them, without any great expenditure of time or money in heavy machinery or fire work. The only piece of heavy machinery required would be a travelling crane, and one such machine of considerable power would be required with any system of iron casemates.

This form of using wrought iron in sea batteries, therefore, meets several of the requirements laid down in this section as very desirable. There are some important ones it does not meet. Such planks are more liable to be broken by deflection than plates of larger area, and when broken, the stability of the shield is injured, and the broken plank particularly is liable to fall out of its place in the shield. In the trial of Captain Inglis's shield, at Shoeburyness, one of the rear planks was broken by deflection. Then if the planks get out of place, or are required to be removed from injuries, the operation of repairing the damage will be a slow and difficult one, though quite practicable.

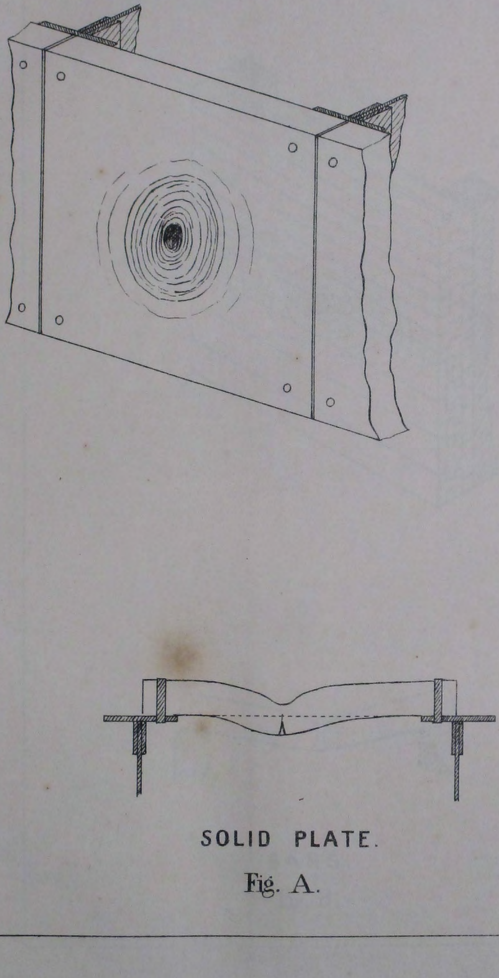
Another form of using wrought iron in fronts of sea batteries, less open to these objections, is *thin plates laid horizontally on each other*, presenting their edges to the projectile, which I will call LAMINATED PLATES. One mode of arranging such plates will be described further on in detail, which will give a more complete idea of its advantages. The principles of it are to unite thin plates together, so that the shield shall form one mass, on which projectiles may expend their force in punching indentations without breaking the whole by cracks. If this can be effected it would be equivalent to making a front in one piece of very ductile iron, and would possess several important advantages. The common plate iron adopted in civil constructions could be used; this can be easily obtained at ordinary prices and of any dimensions that are likely to be required in fortifications. If the plates are riveted together they should not be much less than *one inch thick*, otherwise, the thinner they are the better, as long as they can be made to lay flat on each other.

With these flat plates, and with some special angle plates which would not be more difficult to obtain, and with ordinary angle iron of not unusual dimensions, the whole shield might be erected at the fort; for the only apparatus required would be machines for punching and drilling holes in thin plates and for riveting; the whole front and its supports being put together with rivets; and these operations are constantly done by hand in civil constructions. A front on this plan might be increased in thickness to 2 or 3 feet, without increasing the cost of material or labour beyond that due to the extra thickness, though with equal facility of execution, and with advantage to the principle; because the thicker the front the more it would resemble a solid wall of very malleable iron. It would not be so practicable to repair injuries in it as in the "*plank*" front, but the injuries would be more local; and when the opportunity offered of effecting the repairs thoroughly, they could be done effectively on the same principle, and more of the old iron would be available for use than in most other forms of fronts. If thin plates could be effectively joined together in this manner, it would be a very advantageous form of construction, on account of its simplicity in material and construction, its economy, and its adaptibility to all circumstances of fronts of sea batteries. There have been no experiments made on any front of this kind of construction as far as I am aware; that composed of horizontal beams, and commonly called Thorneycroft's, is not on the same principle.

For roofs of casemates, wrought iron can be applied in two general forms.

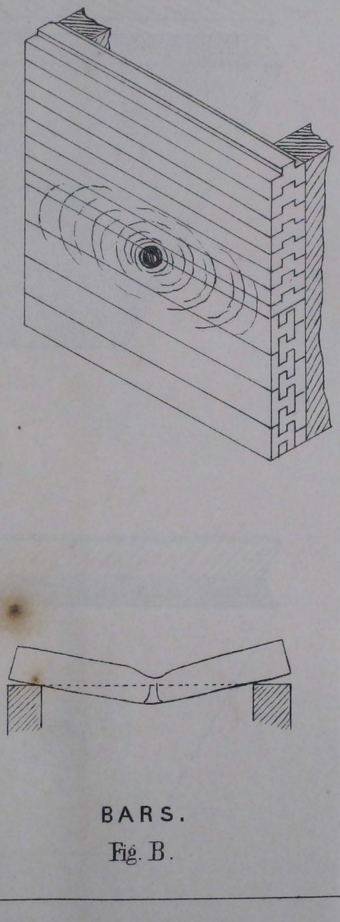
1st. When a roof is required for a small chamber for a special isolated gun, or when for any reason a light roof as thin as practicable is required, then probably the most effective form in which wrought iron can be used is in LARGE SQUARE CURVED PLATES *about* 3 *inches thick*. They should be obtained from the manufactory rolled to the curve required and with the bolt-holes drilled; and they should be joined together with fishing pieces of the same thickness and curve, placed underneath the junction of two plates, the object being to form the roof into one continuous curved plate as nearly as practicable. A curved roof of 3-inch plates so constructed over a span of 16 feet, and containing an arc of about 120° would probably resist a 10-inch shell. If greater strength is required in the roof to resist 13-inch shells, or if the roof is carried down lower on the sides to protect the gun against indirect horizontal fire, then it would be better to use two thicknesses of 3-inch plates, connected together by bolts, than to use a solid curved plate 6 inches thick, because with a slow velocity, or with indirect firing, such a roof will resist more by the elasticity of the whole surface than by the transverse strength of one part.

2nd. When a casemate, or series of casemates, has to be covered with a roof of earth or concrete supported on iron, the most economical form of applying the



SOLID PLATE.

Fig. A.

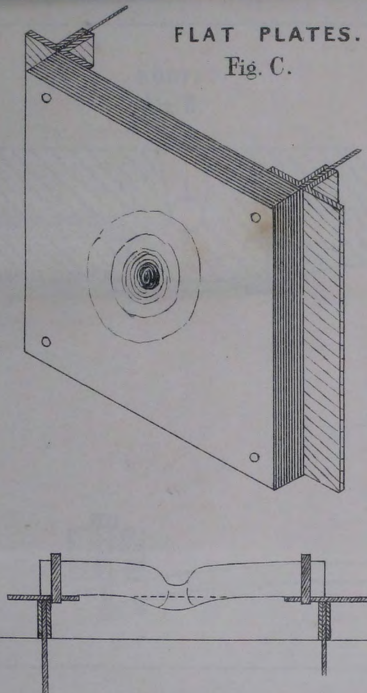


BARS.

Fig. B.

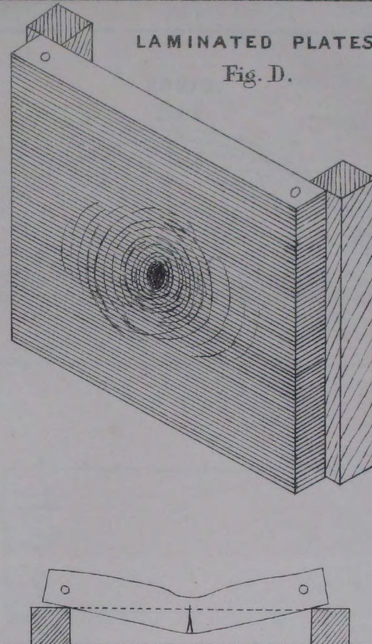
FLAT PLATES.

Fig. C.

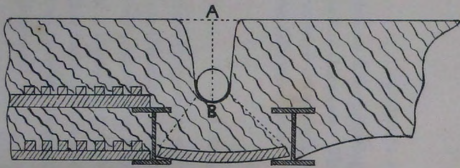


LAMINATED PLATES.

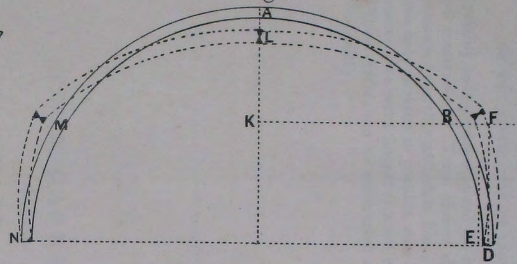
Fig. D.



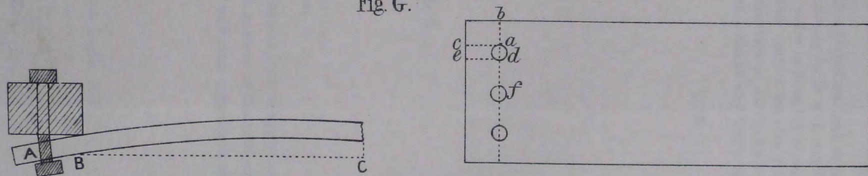
ROOFS.
Fig. E.



ROOFS.
Fig. F.



BOLTS.
Fig. G.



iron will probably be in girders made of the ordinary thin plate iron, such as is used in civil constructions. These girders should be simply built with angle iron, and connected together with thin iron plates, in order to form the whole roof into one body as much as possible, as a considerable part of the strength of such structures to resist impact depends on the connection of all the parts together. These girders can be constructed at the fort without any heavy or expensive machinery.

T. B. C.

IRON CASEMATES.

PART II.

Projects for Iron Casemates.

The descriptions of the following projects for iron casemates form an appendix to the first part of this paper. They are appended to it to serve as illustrations of different principles of applying iron, and to afford as well some comparison of the cost of the different systems.

List of the Projects.

1. Masonry Casemate with Iron Shield; by Capt. Inglis, R.E.
2. Iron Casemate; by Lieut. English, R.E.
3. Iron Casemate; by Lieut. Colonel Collinson, R.E.
4. Iron Casemate; by Capt. Schumann, Prus. Eng.
5. Iron Embrasures in Earth; by do.
6. Iron Moveable Chamber for one gun; by do.
7. Estimates.

T. B. C.

1.—MASONRY CASEMATE WITH IRON SHIELD.

By Captain Inglis, R.E.

The original idea of this casemate was given in a paper read by Capt. Inglis, at Chatham, in 1862; the present form of it, as shewn in drawing No. 1, is slightly modified from that, with the object of reducing it to the smallest dimensions suitable for a 110-pdr. Armstrong gun, mounted on a casemate platform; a horizontal range of 6°, and a vertical range of 5° elevation and 2¼° depression, have been allowed. The iron shield has been copied from a lithographed drawing by Capt. Inglis, slightly modified to fit this casemate; this system of applying wrought iron is not confined to shields for masonry casemates, but it has been introduced here because Capt. Inglis himself has proposed that application; and because this plan of casemate affords a good standard of reference, as regards efficiency and cost, with which to compare the others.

Plate 1.

The iron shield has been so fully described by Capt. Inglis himself, as far as its principle is concerned, in Vols. XI and XII of the Corps Papers, that it is unnecessary to state anything further about it in this paper. The facing of the masonry is composed of massive granite blocks, the remainder of it is of brickwork.

2.—IRON CASEMATE.

By Lieutenant English, R.E.

General Report.

Plates 2 & 3.

The casemate contains two 110-pdr. Armstrong guns, with a central interval of 19 feet. The guns are mounted on new pattern platforms, arranged for casemates, with casemate carriages. Each has a traverse of 90°, 45° on each side of the centre line, and can be elevated 13° or depressed 6°.

Front.

The front of the casemate, to resist horizontal fire, consists of vertical wrought iron bars 15 inches thick, rising the whole height of the casemate. These are shaped like the voussoirs of an arch, and are 11 inches wide at the extrados, and 10⅛ at the intrados.

These voussoirs are arranged side by side so as to form horizontal arches, one between every two guns, to a radius of 13 ft. 9 in.

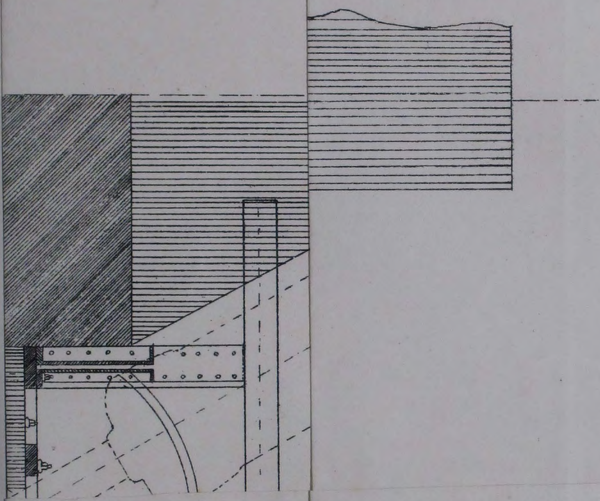
They are sunk in a recess in the masonry 1 foot below the ground, and a 6-in. bar passes through a hole pierced through each 6 inches below the ground, to connect them all together.

At the top each voussoir is notched in front so as to fit the section of an inverted channel-iron which passes along their tops and acts as a coping.

The piers of the arches formed by these voussoirs consist of four wrought iron plates above, and four below the embrasure. The plates below the embrasure are sunk 4 feet into the masonry, and rise about 2 feet above the ground, and are firmly dovetailed together.

The 6-inch bar which runs through the voussoirs also passes through these plates and is nutted to an iron plate resting in masonry inside the casemate.

Plate 1.



The extreme voussoirs on each side of the arch nearest the pier are made of different section to the others, so as to dovetail into the iron plates forming the pier.

Above these plates these voussoirs are enlarged to form the cheeks of the embrasure, and also to receive the bottoms of the four iron plates above the embrasure.

Above the embrasures these voussoirs are the same section as below it.

The iron plates above the embrasure are also supported by being backed by one of the roof arches; they also have a large I-girder, which carries the roof, dovetailed into them, and are fixed in position by the inverted channel-iron which forms the coping.

A beam of teak, 1 ft. × 9 in. in section, is placed in front of those parts of the voussoirs which are imbedded in the masonry, and a precisely similar beam is placed behind them inside the casemate.

A 9-in. backing of teak is also placed before and behind those parts of the plates below the embrasure which rest in the masonry.

At the centre of each arch one of the I-girders which carry the roof is dovetailed through the voussoirs at the top.

The total height from the ground line to the top of the coping is 11 ft. 5 in.

The horizontal arch between two guns forms a circular segment of 60°; between a gun and the masonry forming the side of the casemate is a segment of 30°.

The masonry projects 2 ft. 6 in. beyond the extreme front point of the casemate arch and is rounded off at the top and sides to the iron-work.

Roof. The roof protects a distance of 18 ft. 2 in., measured directly backwards from the inner edge of the embrasure, which is sufficient for a traversing platform when a compressor is used.

If further bomb-proof cover is required, the roof may be extended to the rear by an exactly similar construction to the roofing shewn in the plan.

The roof for each gun portion is supported on four wrought iron pillars at the corners.

The two pillars between two guns serve for both portions. These pillars are made in the form of upright T-girders of rolled iron, and are bedded 4 feet into the masonry and backed before and behind with 9 inches of teak.

At the ground line, the flanges are 18 inches across, $5\frac{1}{2}$ inches deep, and the web 12 inches across and 21 inches deep.

They are formed of rolled iron—four channel-irons and two flat bars, and have five 3-inch through-bolts in the first six feet above ground.

At 6 feet from the ground each pair of these pillars receives a transverse arch 12 inches deep, of three rolled bars of wrought iron placed side by side and joined by through-bolts. The width of each bar is 7 inches. Above these arches the flat bars in the pillars are discontinued, and the section of the web is 21 in. × 6 in.

At 9 feet above the ground the pillars carry longitudinal I-girders extending the whole depth of the roofing, their section being—

	Breadth.		Depth.
Upper flange	24 in.	...	9 in.
Web	6 „	...	9 „
Lower flange	18 „	...	8 „

The front pillars are morticed $4\frac{1}{2}$ inches into these I-girders, whilst the front flange of the rear pillar rises no higher than the bottom of the lower flange of the I-girders; the web of the rear pillars rises to the bottom of the web of the I-girders, and the rear flange of the rear pillars passes through a hole cut to receive it in the upper flange of the I-girder, which thus encircles it like a collar.

The front transverse arch has a rise of 2 feet, and its extrados at the centre is thus 9 feet high. On this is supported another longitudinal I-girder midway between those carried by the piers, and of similar dimensions.

The rear arch has a rise of 3 feet 5 inches, and passes through a hole cut in this I-girder to receive it.

The I-girders consist of four channel-irons joined by through-bolts.

A strut, in the form of a small I-girder of rolled iron,

	Breadth.		Depth.
Upper flange	6 in.	...	2 in.
Web	2 „	...	5 „
Lower flange	6 „	...	2 „

passes diagonally from the centre of the front arch to each of the rear pillars and abuts against their rear flanges, and a tie-beam of 5-inch round iron passes through the rear arch near the centre, diagonally to each front pillar, the front ends of every two being bolted to a saddle of wrought iron attached to the front of the front pillar.

The roofing itself consists of small arched ribs of 9-ft. span laid transversely from one I-girder to the next and close together. These ribs are T-shaped, in section—

	Breadth.		Depth.
Flange	24 in.	...	$2\frac{3}{4}$ in.
Web	$3\frac{3}{4}$ „	...	$6\frac{1}{4}$ „

At their abutting edges they are connected by T-pieces riveted to them by 1-in. rivets, 1 foot apart, of the following section—

	Breadth.		Depth.
Flange	$7\frac{3}{4}$ in.	...	1 in.
Web	$3\frac{3}{4}$ „	...	$5\frac{1}{4}$ „

so that the whole is equivalent to a continuous roof $2\frac{3}{4}$ inches thick, with stiffening ribs 1 foot apart, $3\frac{3}{4}$ in. $\times$ $6\frac{1}{4}$ in. in section.

This roofing rests on the recesses of the I-girders, partially filling up the lateral hollows of the I, the remainders of which are occupied by blocks of teak, which partially transmit the pressure of the roof to the lower flanges of the I's.

The roof is covered with concrete, averaging about 3 inches in thickness, and sloping slightly every way to a point, just above the rear pillars, from which the rain-fall may be carried off.

Remarks. A light iron splinter proof will probably be required for the rear of the casemate.

A convenient form would be in the shape of gates of plate iron, say 1 inch thick, hinged on the rear pillars and made concave to the front to allow the traverse of the gun.

As this would probably not be a permanent arrangement, it has not been included in the design.

At the sides of the casemate the roofing arches are imbedded in horizontal beams of teak resting in the masonry.

The top or flange of each channel-iron coping is secured by two bolts to the upper flange of the I-girder, and the inner web is secured by a bolt to the same; the outer web abuts against the outer face of the plate above the embrasure.

The parts of the iron-work imbedded in the masonry would probably be further secured by iron-ties and cramps running into the masonry; but this would of course entirely depend upon the character of the stone employed.

All the iron-work employed is rolled, with the exception of the extreme voussoirs of each front arch nearest the pier, which are of irregular section and will need forging.

The weight of each of these is estimated at 4 tons.

All the other work may be used directly as it comes from the rolls, as soon as the bolt-holes, &c., have been drilled.

Thin sheet lead may be employed to lay between the joints, or they may be, by preference, united by iron cement.

No camber will be required for any of the beams or arches, since the deflection caused by their own weight is very small.

PRINCIPAL DIMENSIONS.

	ft.	in.
Diameter of muzzle of gun	1	1
Clearance each side	0	2½
Width of port outside	2	3
Ditto inside	5	3½
Height outside	3	6
Ditto inside	2	11½
Depth to floor from bottom sill	2	3½
Radius of front racers	4	9½
Ditto of rear ditto	16	3½
Height of gun from platform	3	9
Ditto of platform, rear	3	6
Ditto ditto, front	1	1
Length of platform	15	11
Distance of front of platform from outer edge of embrasure	3	9
Extreme breadth of platform, rear	4	3
Ditto ditto ditto, rear racer	6	2
Ditto ditto ditto, step	5	10
Distance apart of trucks, front racer	3	0
Extreme breadth of platform, front racer	4	4
Distance apart of trucks, rear racer	3	9
Height of casemate to front arch	8	0
Ditto ditto at piers	6	0
Ditto ditto to I-girders	9	0
Breadth, centre to centre	19	0
Total height of casemate	11	5
Depth of I-girders	2	2
Radius of horizontal arch	13	9

	ft.	in.
Thickness of voussoirs	1	3
Breadth ditto, intrados	0	$10\frac{1}{8}$
Ditto ditto, extrados	0	11
Number of voussoirs	15	
Breadth of extreme voussoirs, intrados	0	11
Diameter of bottom through-bolt	0	6
Area of section	0	$28\frac{1}{4}$ sq. in.
Pitch of thread on screw	0	$\frac{2}{3}$
Projection	0	$\frac{1}{3}$
Effective breadth of screw	0	$5\frac{1}{3}$
Head of bolt, octagon	0	11 over all
Length of head	0	5
(Half these dimensions for the 3-in. bolts).		
Depth of washer	0	12
Thickness of table of washer	0	$2\frac{1}{2}$
Ditto wings	0	3
Length of wings on inside	2	0
Radius of masonry arch	1	8
Breadth of main arches	1	9
Span	18	0
Radius of intrados, front arch	19	5
Ditto ditto, rear arch	12	5
Depth of arch	1	0
Rise of front arch	2	0
Ditto rear arch	3	5
Span of I-girders	13	9
Area of section, upper flange	216 sq. in.	
Ditto ditto, web	54 sq. in.	
Ditto ditto, lower flange	144 sq. in.	
Extreme length of pillars	15	5
Area of section, each flange	99 sq. in.	
Ditto ditto, web below arches	252 sq. in.	
Ditto ditto, above arches	126 sq. in.	

CALCULATIONS.

To find the equations of motion for a beam when extended or compressed by a shot striking it longitudinally.

Let W be the weight of the shot, V the velocity, l the length of the beam, B its weight, A the area of section, E the modulus of elasticity.

To determine r, the total extension.

If all the particles were free to move till each is separated from the next by a distance dr.

Let v' be the velocity of the shot, when it has moved through a space x after striking.

$$\text{then } v' = \frac{W}{W + B} \int_o^x \frac{dx}{r} \cdot V.$$

This will evidently hold good whether we suppose the first particle to move through a space dx, and then the next, and so on, like the links of a chain if lifted from the ground, or if they all move at first through a space $d\,(dx)$

$$\therefore \text{ integrating, } v' = \frac{W}{W + B\frac{x}{r}} . V$$

$$\text{differentiating } \frac{dv'}{dx} = - \frac{BWV}{r\left(W + B\frac{x}{r}\right)^2}$$

and the retardation from the inertia of the beam $= f' = \dfrac{v'dv'}{dx} = - \dfrac{BW^2V^2}{r\left(W + B\frac{x}{r}\right)^3}$

Let f'' be the further retardation due to the extension of the beam, supposed without weight, then $- \dfrac{W}{g} \cdot f'' : Ea = x : l, \therefore f'' = - \dfrac{Eag}{Wl} . x$

The total retardation $f = f' + f'' = v \dfrac{dv}{dx}$

$$\therefore v \frac{dv}{dx} = - \left(\frac{BW^2V^2}{r\left(W + B\frac{x}{r}\right)^3} + \frac{Eag}{Wl} . x \right)$$

Integrating,

$$\frac{v^2}{2} = C - B W^2 V^2 r^2 \int_o^x \frac{dx}{(Wr + Bx)^3} - \frac{Eag}{Wl} \int_o^x x = C + \tfrac{1}{2} \frac{W^2 V^2 r^2}{(Wr + Bx)^2} - \frac{Eagx^2}{2\,Wl}$$

Let $x = o$, then $v = V$, and $\dfrac{V^2}{2} = C + \dfrac{V^2}{2} \therefore C = O$

$$v^2 = \frac{W^2 V^2 r^2}{(Wr + Bx)^2} - \frac{Eag\, x^2}{Wl}$$

Let $v = o$, then $x = r$, and $\dfrac{W^2 V^2}{(W + B)^2} = \dfrac{Eag.r^2}{Wl}$

$$r = \frac{W V}{W + B} \sqrt{\frac{Wl}{Eag}}$$

The tensile or compressive force due to the extension or compression $F : Ea = r : l$

$$\text{hence force } F = \frac{W V}{W + B} \sqrt{\frac{Wl}{Eag}} . \frac{Ea}{l} = \frac{W V}{W + B} \sqrt{\frac{WEa}{gl}}$$

and this is evidently the greatest force which acts on the beam.

To find the time t of extending or compressing the beam,

$$\text{we have } \frac{dx}{dt} = v = \sqrt{\frac{W^2 V^2 r^2}{(Wr + Bx)^2} - \frac{Eag}{Wl} . x^2}$$

$$\text{and } t = \int_o^r \frac{dx}{\sqrt{\frac{W^2 V^2 r^2}{(Wr + Bx)^2} - \frac{Eag}{Wl} . x^2}}$$

this, I have not yet been able to integrate ; probably a near approximation will be to assume that the velocity diminishes uniformly, in this case

$$t = \frac{2r}{V} = \frac{2W}{W + B}\sqrt{\frac{Wl}{Eag}}$$

It is evident that, in applying these formulæ to a beam or plate, the thickness of the plate must be put for l, and the area for a, and we shall then obtain the shearing force of the shot, at right angles to the beam or plate, which produces either punching or breaking by deflection. In the following calculations as it is impossible to ascertain the velocity with which compressions are transmitted over the surface of a plate, I have assumed the compressions to extend equally in all directions, which will not probably be far from the truth.

Plating of Embrasures.

To find the depth to resist breaking-deflection, the plate being 6 feet broad, struck at 3 feet from bearing, the weight moved, including the shot, being 15,000 lbs., shot weighing 150 lbs., velocity 1,200 feet per second.

If l be the length, b the breadth, d the depth, t the extreme tensile strain

$$\text{bending moment} = \frac{W\,V}{W + B}\,l.\sqrt{\frac{WEbl}{gd}}$$

$$\text{and } \frac{t}{6}\,bd^2 = \frac{W\,V}{W + B}\sqrt{\frac{WEbl^3}{gd}},\quad d^{\frac{5}{2}} = \frac{6}{t}\,\frac{W\,V}{W + B}\sqrt{\frac{WEl^3}{bg}}$$

If $t = 60{,}000$, and $E = 30{,}000{,}000$,

$$d^{\frac{5}{2}} = \frac{6}{60000} \times \frac{150 \times 14400}{15000}\sqrt{\frac{150 \times 30{,}000{,}000 \times 36^3}{32 \times 12 \times 72}}$$

$$d^{\frac{5}{2}} = 14{\cdot}4\sqrt{\frac{150}{32} \times \frac{36^2}{12} \times 15}$$

$$= 14{\cdot}4 \times 2{\cdot}1 \times 36\sqrt{\frac{5}{4}}$$

$$= 544{\cdot}32\,\sqrt{5}$$

$$= 1218{\cdot}27$$

$$\log d = \tfrac{2}{5}\,(3{\cdot}0857542)$$

$$= 1{\cdot}2343$$

$$d = 17{\cdot}15 \text{ inches}$$

To find the punching effect of a 10-in. shot in iron weighing 480 lbs. per cubic foot. If 40,000 be the maximum shearing strain in pounds per square inch, 10 in. the diameter of the shot, so that 31·4 in. is the circumference of the hole punched, and assuming the shot to be perfectly hard, we have

$$40{,}000 \times 3{\cdot}14 \times d = \frac{150 \times 1200 \times 12}{150 + \frac{480}{1728} \times \pi\,(5 + d)^2 \times d}$$

$$\times\sqrt{\frac{150 \times 30{,}000{,}000 \times \pi\,(5 + d)^2}{32 \times 12 \times d}}$$

and neglecting the weight of the shot in (W + B), in order to solve the equation,

$$d^{\frac{5}{2}} (5 + d) = \frac{150 \times 1200 \times 12}{40000 \times 31{\cdot}4 \times \frac{480}{1728} \times \pi} \sqrt{\frac{150 \times 30{,}000{,}000 \times \pi}{32 \times 12}}$$

$$= 12000 \text{ nearly.}$$

$$\text{and } d = 13 \text{ in. nearly.}$$

The thickness of the plating is made 18 inches.

Voussoirs.

As the voussoirs are supported by each other against breaking by deflection, their resistance to punching only has been considered, and they have consequently been made 15 inches thick.

Roofing.

The roofing is liable to be struck by mortar shells weighing 200 lbs., with a terminal velocity of 500 ft. per second.

It is perfectly impossible to estimate by calculation the punching effect of one of these shells, as the shell would be broken up.

The roof is therefore made $2\frac{3}{4}$ in. thick to resist punching, as that appears by experiment to be capable of stopping a projectile of this class.

I-Girders.

These are made to offer the same resistance to crushing and tearing.

Assume the span as 14 ft. 8 in., that is, that the bearing commences on the web of the front and rear pillars, and the breadth (mean) to be 18 in.

If f_a be the modulus of resistance to crushing,

$$f_a = \frac{36000}{1 + \frac{l^2}{5000\, b^2}} = \frac{36000}{1 + \frac{100}{5000}}$$

$$= 36000 \times \frac{50}{51}$$

$$= 35294 \text{ lbs.}$$

f_b, modulus of resistance to tearing = 50000 lbs.

Let in the upper flange A_1 be the area, h_1 be the depth

web A_2 " h_2 "

lower flange A_3 " h_3 "

Total $A_1 + A_2 + A_3 = A$; $h_1 + h_2 + h_3 = h$

Let y_b be the height of neutral axis from lower side

$$y_b = \frac{h}{2} - \frac{(h_2 + h_3) A_3 - (h_1 + h_2) A_1 - (h_3 + h_1) A_2}{2 A}$$

moment of inertia $I = \frac{A_1 h_1^2 + A_2 h_2^2 + A_3 h_3^2}{12} = \frac{1}{4A}\Big(A_1 A_3 (h_1 + h_3 + 2h_2)^2$

$$+ A_1 A_2 (h_1 + h_2)^2 + A_2 A_3 (h_2 + h_3)^2\Big)$$

moment of resistance $M = \frac{f_b I}{y_b}$

Let $h^1 = h_2 + \frac{h_1 + h_3}{2}$

$$y_b = \frac{h^1}{2}\left(- \frac{A_3 - A_1}{A}\right) = \frac{h^1}{2}\left(\frac{A_2 + 2A_1}{A}\right)$$

$$I = h^{12}\left(\frac{A_2}{12} + \frac{A_2 A_3 + A_1 A_2 + 4 A_1 A_3}{4A}\right)$$

$$M = \frac{f_b I}{y_b} = \frac{f_b h^1}{6} A_2 \frac{(A_2 + 4 A_1 + 4 A_3) + 12 A_1 A_3}{A_2 + 2 A_1}$$

$$\text{but } A_1 = \frac{f_b}{f_a} A_3 + \frac{f_b - f_a}{2 f_a}$$

in order that the resistance to crushing and tearing may be equal,

$$M_o = h^1 \left(f_b A_3 + 2 (f_b - f_a) \frac{A_2}{6}\right)$$

$$= h^1 \left(f_a A_1 + 2 (f_a - f_b) \frac{A_2}{6}\right.$$

In this case $A_1 = \cdot21 A_2 + 1\cdot41 A_3$

$$\frac{M_o}{h^1} = 10\cdot784 A_2 + 50000 A_3$$

To determine A_2

If F be the vertical force expended by a mortar shell.

$$F = \frac{W V}{W + B}\sqrt{\frac{W}{g} \cdot \frac{Ea}{l}}$$

Here $a = 18 \times 176$, and assuming the depth $= h^1$ as 18″, and that a weight of 33,200 lbs. is put in motion, which is the weight of half a span of the roofing and the girder itself,

$$F = \frac{200 \times 500 \times 12}{332000}\sqrt{\frac{200 \times 30{,}000{,}000 \times 18 \times 176}{12 \times 32 \times 18}}$$

$$= 3000 \times 12 \sqrt{\frac{200 \times 30 \times 176}{32 \times 12}}$$

$$= 30000 \sqrt{330 \times 12}$$

$$= 30000 \times 63$$

$$= 1{,}890{,}000 \text{ lbs.}$$

The ultimate resistance of the web to shearing, if t is the thickness,

$$= \frac{36000}{1 + \frac{h_2^2 \text{ Sin}^2 45}{3000\ t^2}} = \frac{36000}{1 + \frac{9^2 \text{ Sin}^2 45}{3000\ t^2}}$$

$$= 36000\ t^2 \times \frac{60}{63} \text{ nearly}$$

$$t^2 \frac{36000 \times 60}{63} = 1{,}890{,}000$$

$$t^2 = \frac{63}{60} \times 52{\cdot}5 = 55 \text{ nearly}$$

$$t = 7\tfrac{1}{2} \text{ inches}$$

Since a part of the shearing strain is borne by the top and bottom flanges, it will be safe to make $t = 6$ in.

Since $h^1 = 18$, area $A_2 = 6 \times 18 = 108$

$$\frac{M_o}{18} = 10{\cdot}784\ A_2 + 50000\ A_3$$

$$M_o = 18\ (10{\cdot}784 \times 108 + 50000\ A_3)$$

$$M_o = \frac{Fl}{4} + \frac{Wl}{8}, \text{ if W be the weight of the girder}$$

$$= 33000 \times \frac{176}{8} + 1{,}890{,}000 \times \frac{176}{4}$$

$$44\ (15500 + 1{,}890{,}000) = 18\ (10{\cdot}784 \times 108 + 50000\ A_3)$$

$$\text{nearly } \frac{84{,}000{,}000}{18} = 10{\cdot}784 \times 108 + 50000\ A_3$$

$$50000\ A_3' = 4{,}700{,}000 - 1{,}164{,}000$$

$$= 3{,}536{,}000$$

$$A_3 = 71$$

If 2 be the factor of safety, $A_3 = 142$

A_3 is taken as 144 which gives $h_3 = \frac{144}{18} = 8''$

$$A_1 = {\cdot}21 \times 108 + 1{\cdot}41 \times 144$$

$$= 22 + 202$$

$$= 224, \text{ hence } h_1 = 9'' \text{ nearly.}$$

Roofing.*

The span of the bent ribs of the roof between supports is 9′ 6″ — 1′ 6″ = 8′ 0″.

Assume the neutral axis to be a parabola, to which a flat circular segment approximates, and the rise as 1 ft.

If the abutments are immoveable, and the ends fixed in direction,

Let k be the rise, and l the span

The equation to the curve is $y = \frac{4k}{l^2}\left(\frac{l}{2} - x\right)^2$

$$\frac{dy}{dx} = -\frac{8k}{l^2}\left(\frac{l}{2} - x\right), \quad \frac{d^2y}{dx^2} = \frac{8k}{l^2}$$

$$1 + \left(\frac{dy}{dx}\right)^2 = 1 + \frac{64\,k^2}{l^4}\left(\frac{l}{2} - x\right)^2,$$

$$\text{and} \int_o^l \left(1 + \left(\frac{dy}{dx}\right)^2\right) dx = l + \frac{16}{3}\,\frac{k^2}{l}.$$

$$\frac{dy_o}{dx_o} = -\frac{4\,k}{l}, \text{ at one end.}$$

If i be the alteration of slope, caused by the load, v the deflection.

$$\int_o^l i\,\frac{dy}{dx}\,dx = \int_o^l \frac{dy}{dx}\,dv. \quad \text{and} \; -\int_o^l \frac{d^2y}{dx^2}\,vdx = -\frac{8\,k}{l^2}\int_o^l vdx.$$

Let the rib be under a uniform fixed load of W_o per horizontal linear inch, and a load P applied at a point $(1 - r)\,l$ distant from the origin, and let the formula (A) refer to the part nearest the origin, and (B) to that furthest from the origin.

Shearing force $F = F_o - \int_o^x wdx + H\left(\frac{dy}{dx} - \frac{dy_o}{dx_o}\right)$ where H is the horizontal pressure.

$$\text{(A)} \quad F = F_o + \left(\frac{8\,k}{l^2}\,H - w_o\right)x$$

$$\text{(B)} \quad F = F_o + \left(\frac{8\,k}{l^2}\,H - w_o\right)x - P$$

$$\text{Bending moment} \quad M = M_o + \int_o^x F dx$$

$$\text{(A)}\; M = M_o + F_o x - \int_o^x \int_o^x w dx^2 - H\left(y_o - y + x\,\frac{dy_o}{dx_o}\right)$$

$$\text{but } H\left(y_o - y + x\,\frac{dy_o}{dx_o}\right) = H\left(k - y - \frac{4\,kx}{l}\right) = H\left(\frac{4\,kx^2}{l^2}\right)$$

* The calculations respecting the strength of arched ribs are deduced from Professor Rankine's work on "Applied Mechanics."

$$\text{and } M = M_o + F_o x + \left(\frac{8\,k\,H}{l^2} - W_o\right)\frac{x^2}{2}$$

$$\text{(B) } M = M_o + F_o x + \left(\frac{8\,k\,H}{l^2} - W_o\right)\frac{x^2}{2} - P\left(x - l\,(1 - r)\right)$$

Alteration of slope. Let A_1 = area

$$i = l_o - \frac{1}{E\,I}\int_o^x m dx, \qquad m = \frac{y_1}{h}, \qquad q = \frac{I}{mh^2\,A_1}$$

$$\text{(A)} = \frac{1}{qmh^2\,E\,A_1}\left(-M_o x - F_o\frac{x^2}{2} - \left(\frac{8\,k\,H}{l^2} - W_o\right)\frac{x^3}{6}\right)$$

(B) to the factor in brackets add $+\dfrac{P}{2}\left(x - l\,(1 - r)\right)^2$

Deflection $\qquad v = \int_o^x i\,dx$

$$\text{(A)} = \frac{1}{qmh^2\,E\,A_1}\left(-M_o\frac{x^2}{2} - F_o\frac{x^3}{6} - \left(\frac{8\,k\,H}{l^2} - W_o\right)\frac{x^4}{24}\right)$$

(B) to the factor in brackets add $+\dfrac{P}{6}\left(x - (1 - r)\,l\right)^3$

Since the ends are fixed,

$$i_1 = 0 \;\therefore\; -M_o - F_o\frac{l}{2} - \left(\frac{8\,k\,H}{l^2} - W_o\right)\frac{l^2}{6} + \frac{Pr^2}{2}\,l = 0 \quad (1)$$

$$\text{and } v_1 = 0 \;\therefore\; -\frac{M_o}{2} - F_o\frac{l}{6} - \left(\frac{8\,k\,H}{l^2} - W_o\right)\frac{l^2}{24} + \frac{Pr^3}{6}\,l = 0 \quad (2)$$

If U be the horizontal displacement of any point in the arch,

$$U = -\frac{H}{EA_1}\int_o^x \left(1 + \left(\frac{dy}{dx}\right)^2\right)dx - \int_o^x i\,\frac{dy}{dx}\,dx$$

Since the abutments are immoveable $U_1 = 0$

$$\therefore 0 = -\frac{H}{EA_1}\left(l + \frac{16\,k^2}{3l}\right) + \frac{8\,k}{l^2}\int_o^l i\,dx$$

$$= \frac{1}{qmh^2\,EA_1} \times \frac{8\,k}{l^2}\left\{-\frac{M_o\,l^3}{6} - \frac{F_o\,l^4}{24} - \frac{8\,k\,Hl^3}{120} + \frac{W_o\,l^5}{120} + \frac{Pr^4\,l^4}{24}\right\}$$

$$-\frac{H}{EA_1}\left(l + \frac{16\,R^2}{3l}\right)$$

Multiply both sides by $\frac{qmh^2 \; EA_1}{8kl}$

$$0 = -\frac{M_o}{6} - \frac{F_o l}{24} + \frac{W_o l^2}{120} + \frac{Pr^4 l}{24} - H\left\{\frac{k}{15} + \frac{qmh^2}{8k}\left(1 + \frac{16k^2}{3l^2}\right)\right\} \quad (3)$$

Multiply (2) by 2

$$-M_o - F_o\frac{l}{3} - \left(\frac{8kH}{l^2} - W_o\right)\frac{l^2}{12} + \frac{Pr^3 l}{3} = 0 \quad (4)$$

Subtracting (4) from (1)

$$F_o\frac{l}{6} + \left(\frac{8kH}{l^2} - W_o\right)\frac{l^2}{12} + Pl\left(\frac{r^3}{3} - \frac{r^2}{2}\right) = 0$$

Multiplying by 2

$$F_o\frac{l}{3} + \left(\frac{8kH}{l^2} - W_o\right)\frac{l^2}{6} + \frac{Pl}{3}(2r^3 - 3r^2) = 0 \quad (5)$$

Adding (4) to (5)

$$-M_o + \left(\frac{8kH}{l^2} - W_o\right)\frac{l^2}{12} + Pl(r^3 - r^2) = 0$$

Substituting in (3)

$$0 = -\frac{8kH}{72} + \frac{W_o l^2}{72} - \frac{Pl}{6}(r^3 - r^2) + \frac{8kH}{48} - \frac{W_o l^2}{48} + \frac{Pl}{4}\left(\frac{r^3}{3} - \frac{r^2}{2}\right)$$

$$-\frac{kH}{15} + \frac{W_o l^2}{120} + \frac{Pl}{4}\frac{r^4}{6} - H\frac{qmh^2}{8k}\left(1 + \frac{16k^2}{3l^2}\right)$$

$$0 = -kH\left(\frac{1}{9} + \frac{1}{15} - \frac{1}{6}\right) + W_o l^2\left(\frac{1}{72} + \frac{1}{120} - \frac{1}{48}\right)$$

$$-\frac{Pl}{12}\left(2r^3 - 2r^2 - r^3 + \frac{3}{2}r^2 - \frac{r^4}{2}\right) - H\frac{qmh^2}{8k}\left(1 + \frac{16k^2}{3l^2}\right)$$

$$kH\left\{\frac{qmh^2}{8k^2}\left(1 + \frac{16k^2}{3l^2}\right) + \frac{1}{90}\right\} = \frac{W_o l^2}{720} + \frac{Pl}{24}(r^2 - 2r^3 + r^4)$$

$$\text{Let } 45\frac{qmh^2}{4k^2}\left(1 + \frac{16k^2}{3l^2}\right) = B$$

$$\text{then } kH\left(\frac{B}{90} + \frac{1}{90}\right) = \frac{W_o l^2}{720} + \frac{30\,Pl}{720}(r^2 - 2r^3 + r^4)$$

$$H = \frac{l}{8(1+B)k}\left(W_o l + 30\,P(r^2 - 2r^3 + r^4)\right)$$

$$-M_o = -\frac{8k}{12}H + \frac{W_o l^2}{12} - Pl(r^3 - r^2)$$

$$= -\frac{2}{3}k\frac{l}{8(1+B)k}\left(W_o l + 30\,P(r^2 - 2r^3 + r^4)\right) + \frac{W_o l^2}{12} - Pl(r^3 - r^2)$$

$$- M_o = - \frac{W_o\, l^2}{12(1 + B)} + \frac{W_o\, l^2}{12} - \frac{5}{2}\, \frac{Pl}{1 + B}\, (r^2 - 2r^3 + r^4) - Pl\, (r^3 - r^2)$$

$$= \frac{W_o\, l^2}{12} \cdot \frac{B}{1 + B} + Pl\, \left(r^2 - r^3 - \frac{5}{2} \cdot \frac{r^2 - 2r^3 + r^4}{1 + B}\right)$$

$$- M_1 = - M_o - F_o\, l - \left(\frac{8\, k\, H}{l^2} - W_o\right) \frac{l^2}{2} + Plr$$

$$= \frac{W_o\, l^2}{12} \cdot \frac{B}{1 + B} + Pl\, \left(r + r^2 - r^3 - \frac{5}{2} \cdot \frac{r^2 - 2r^3 + r^4}{1 + B}\right)$$

$$+ \left(\frac{8\, k\, H}{l^2} - W_o\right) \frac{l^2}{2} + Pl\, (2r^3 - 3r^2) - \left(\frac{8\, k\, H}{l^2} - W_o\right) \frac{l^2}{2}$$

$$- M_1 = \frac{W_o\, l^2}{12} \cdot \frac{B}{1 + B} + Pl\, \left(r - 2r^2 + r^3 - \frac{5}{2} \left(\frac{r^2 - 2r^3 + r^4}{1 + B}\right)\right).$$

Intensity of thrust per square inch at the loaded end, p_1

$$= \frac{1}{A_1} \left(H + \frac{M_1}{qh}\right) = \frac{l}{8\, A_1\, k\, (1 + B)}\, (W_o\, l + 30\, P\, (r^2 - 2r^3 + r^4)$$

$$+ \frac{W_o\, l^2\, B}{A_1\, 12\, qh\, (1 + B)} + \frac{Pl}{A_1\, qh} \left(r - 2r^2 + r^3 - \frac{5}{2}\, \frac{r^2 - 2r^3 + r^4}{1 + B}\right)$$

$$p_1 = \frac{l}{8 A_1} \left\{ \frac{W_o\, l}{1 + B} \left(\frac{2}{3}\, \frac{B}{qh} + \frac{1}{k}\right) + P \left\{ \frac{8}{qh}\, (r + r^2 - r^3) \right.\right.$$

$$\left.\left. - \frac{5}{2} \left(\frac{r^2 - 2r^3 + r^4}{1 + B}\right) \left(\frac{8}{qh} - \frac{12}{k}\right)\right\}\right\}$$

here $P = \frac{W\, V}{W + B} \sqrt{\frac{WEa}{gl}}$, and considering B = weight of whole span, a the area of ½ the span = $8 \times 7 = 56$, $l = 15''$ since $k = 12''$, and $h = 3''$

$$P = \frac{200 \times 500 \times 12}{33000} \sqrt{\frac{200 \times 30{,}000{,}000 \times 56}{\frac{32 \times 5}{4}}}$$

$$= 36000\, \sqrt{200 \times 30 \times \frac{7}{5}}$$

$$= 360000 \sqrt{\frac{420}{5}}$$

= 3240000 is the pressure on the whole roof

and neglecting W_0 [illegible]

= [illegible]

= [illegible]

= [illegible]

If [illegible] be the factor of safety, moment of resistance should = [illegible]

If the beam break by tearing

$M =$ [illegible]

= [illegible]

Horizontal thrust = [illegible]

= [illegible]

= [illegible]

= [illegible] lbs.

Main Arches—Front.

These are rectangular, span = l = [illegible] = [illegible], b = [illegible], h = [illegible], h = [illegible] A_1 = [illegible].

Assuming P = [illegible] as in the last page, and to be equally divided between the front and rear arches, [illegible] is to be carried by each.

I = [illegible]

[illegible]

[illegible]

= [illegible]

[illegible]

= [illegible]

= [illegible]

therefore $p_{\iota} = 11700$ which gives a factor of safety of $3\frac{1}{2}$.

$$M = 210 \times 1,800,000 \left(1 - \frac{5}{4} \cdot \frac{1}{1 \cdot 25}\right) = 0$$

$$\text{horizontal thrust} = \frac{1}{8 \times 1 \cdot 25 \times 24} \left(30 \times 1,800,000 \times \tfrac{1}{2} \times \tfrac{1}{8}\right)$$

$$= \frac{1,800,000}{16 \times 8} = 50125$$

$$\text{Shearing strain at abutments } F \frac{210}{6} = - 8 \times \frac{24}{12} \times 50,125 + 1,800,000 \times \frac{210}{12}$$

$$F = - \frac{96}{210} \times 50,125 + 900,000$$

$$= - 23,000 + 900,000$$

$$= 877,000 \text{ lbs.}$$

Rear Main Arches.

The pressure on these is evidently less than on the front ones, since k is here 40 instead of 12; the same scantling has however been adopted for them, for convenience-sake, and to resist the shearing force, which remains constant.

Rear and Front Piers.

Maximum downward pressure on one pier

= $\frac{1}{2}$ wt. of 2 main arches
+ $\frac{3}{4}$ wt. of one I-girder
+ wt. of $\frac{1}{2}$-span roofing + wt. of shell falling
= 15708
+ 19800
+ 16500

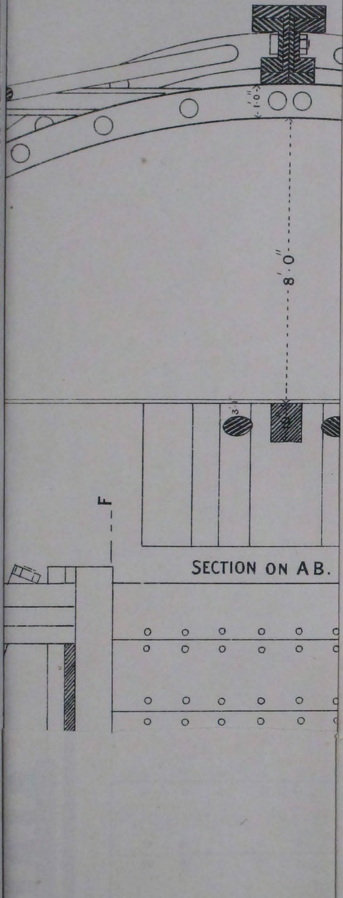
52008 lbs. + wt. of shell falling

$$\left.\begin{array}{l}\text{F, the weight of shell falling,}\\ \text{assuming it to move 36000 lbs.}\end{array}\right\} = \frac{200 \times 500 \times 12}{36000} \sqrt{\frac{200 \times 30,000,000 \times \frac{3}{4}' \times \frac{3}{2}'}{32 \times 8}}$$

$$= \frac{33000 \times 5}{16} \sqrt{30 \times 21}$$

$$= 258000$$

Total downward pressure on pier = 310,000 lbs.


1'0"
8'0"
3"
F
SECTION ON AB.

If the factor of safety for the masonry footings be 6, and 4000 lbs. the crushing pressure,

$$\text{area} = \frac{310000}{700} = 440$$

The area is 460 square inches.

If a shot strike an I-girder horizontally, the force producing a bending moment on rear pier,

$$F = \frac{150 \times 1500 \times 12 \times 1000}{40000} \sqrt{\frac{150 \times 30 \times 414}{32 \times 18 \times 12 \times 12}}, \text{ if 40000 lbs. is moved}$$

$$= 15 \times 325 \times 2{\cdot}1 \times 26$$

$$= 266{,}000 \text{ lbs.}$$

If 4 is the factor of safety, 36000 the ultimate resistance,

$$4 \times 266{,}000 \times 9 \times 12 = 6000 \times 18 \times d^2$$

$$4 \times 266 = d^2$$

$$d = 32, \text{ the depth from point to rear.}$$

Struts and Ties.

If a shot strike an I-girder the pressure is the same as for the rear piers,

$$\text{or} = 266{,}000 \text{ lbs.}$$

If the factor of safety $= 4$

Resistance of strut or tie $= 1{,}064{,}000$

The struts and ties are inclined to the direction of the shot at

$$\sin^{-1} \frac{17\frac{1}{2}}{\sqrt{(17\frac{1}{2})^2 + 9^2}} = \sin^{-1} \frac{7}{8}$$

hence total resistance $= 1{,}216{,}000$

$$\text{Area of tie} = \frac{1{,}216{,}000}{60{,}000} = 20''. \text{ Tie is } 5'' \text{ diam.}$$

$$\text{Area of strut} = \frac{1{,}216{,}000}{36{,}000} = 36''. \text{ The strut is an I-girder } 34'' \text{ area.}$$

T. E.

3.—Description of an IRON CASEMATE of LAMINATED PLATES,

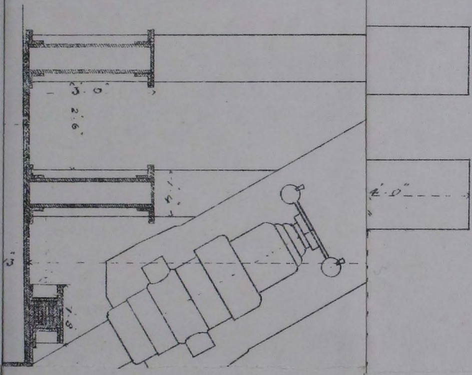
By Lieutenant Colonel Collinson, R.E.

Plates 4 & 5. The dimensions of the different parts of this casemate have been based on theoretical calculations; the front part of it is supposed to resist an elongated projectile of 150 lbs. weight and 8 inches diameter, striking with a velocity of 1,200 feet per second; the roof part to resist a 13-inch shell weighing 200 lbs., and falling with a velocity of 600 feet per second, and penetrating 18 inches into the concrete. But in the present state of our knowledge of the effect of impact of projectiles, such calculations are not to be relied on for determining dimensions; their chief use at present must be only to determine principles of construction. This design must therefore be taken rather as an illustration of the principle of this mode of applying wrought iron to casemates, and to shew how it can be increased and adapted to other projectiles and conditions.

The general dimensions of the casemate have been assumed arbitrarily; it is intended for one 100-pdr. rifled gun mounted on a casemate platform, the dimensions of which have been supplied from the Royal Carriage Department at Woolwich. A horizontal range of 30° on each side of the centre line, and a vertical range of 5° elevation and $2\frac{1}{2}$° depression, have been assumed. The gun is made to pivot horizontally on a point 1 foot behind the muzzle, by which the muzzle just touches the outer edge of the embrasure at its extreme traverse; the elevation and depression are obtained in the ordinary manner by pivoting on the trunnions. The total width of the gun chamber is 16 feet, which is considered the minimum that should be given to a large gun. The depth is 22 feet, which leaves sufficient space for the platform to traverse; the height from floor to ceiling of the front part of the casemate is 7 feet, and of the rear part at the sides 8 feet, and in the centre $8\frac{1}{2}$ feet.

The principles of its construction will be best explained by describing the actual process that would be followed in erecting it.

First, a rectangular frame is made of a horizontal floor-rib, a horizontal roof-rib, and two piers, the two ribs being each composed of a kind of box girder about 14 in. × 16 in., and 12 feet long, and the piers of a kind of case 16 inches wide, $3\frac{1}{2}$ feet long, and 7 feet high, the whole being about 12 feet by 7 feet in the clear, and the whole made of 1-inch plate and angle-iron riveted together. Against the front of this is fastened a *skin* of 1-inch plate by rivets. A second horizontal roof-rib is framed across from pier to pier at their inner ends, also at 7 feet from the floor; from the same point in each pier a roof-girder (formed of a single solid plate of I-shape, about 12 in. by 24 in., and $18\frac{1}{2}$ feet bearing), extends to the back of the casemate; under each pier a floor-girder extends from front to rear; and the ends of the roof and floor-girders are connected with a frame of four pieces at the back similar to, but slighter, than that at the front. Across from one roof-girder to the other are fixed curved roof-ribs at central intervals of 3 feet, and of box-section similar to the horizontal ribs, and having consequently a 12-ft. bearing; the roof-ribs, both horizontal and curved, are connected with curved *late 4.*



1-in. plates riveted to their upper flanges. Thus at this stage of the construction the casemate will be a great iron box about 12 feet wide, 22 feet long and 8 feet high, made of ribs covered and connected in front and on the top with plate iron.

The armour plating is added to the front by riveting 1-in. angle plates 12 in. × 4 in. to the skin, which will therefore be at vertical intervals of 4 inches; the intervening spaces are filled in with 1-in. flat plates, 11 inches wide, which are riveted to the angle plates and to each other by 1-in. bolts vertically. To effect this, it is necessary to build up the plating from the bottom; the vertical bolts pass through four intervening flat plates, and the two angle plates above and below them, in which the bolt-holes must be drilled conically to afford space to form a conical head at each end of the bolt. The object of this arrangement is to connect the whole of the front plates together into one mass, by means of a great number of small fastenings, so that both the plates and the fastenings must be destroyed piece-meal over a large extent of the front, before it is rendered useless.

The roof is covered with 4 feet of concrete resting on the curved plates and curved ribs. An arch of common concrete, 17 feet span and 4 feet thick, without any support underneath, was experimented on at Woolwich in 1824, and was then considered to be proof against 13-inch shells. This form of roof, combining the elastic wrought iron with the hard granular concrete, is the most economical and effective that can be used for this purpose. A solid masonry arch requires solid masonry piers to carry it; it gives an unnecessary and injurious height in the centre; it requires protection in front; and it does not afford a satisfactory support to the iron front which protects it. A combination of brick arches with iron girders are liable to dislocation, as has been already pointed out. The uniform mass of concrete spreading over the iron plates forms a comparatively flat roof, which must be destroyed bit by bit to render it inefficient, and which requires only a thin facing in front. But the great advantage of the combination of iron and concrete, and which is the reason why iron plates are proposed for the connection of the ribs, is that by thus connecting the roof with the front and also with the floor, the whole casemate is united into one mass; and the roof and floor both assist to take up the shock of any impact on the front; this is an important consideration in dealing with iron fronts. The iron part of the roof is in fact a large plate-girder laid horizontally on the front and rear walls. And to carry out this principle as much as possible, great attention should be paid to the riveting of the roof and front together.

The iron roof also has the advantage of affording a great extent of interior space clear of obstructions; a series of casemates so constructed would in fact form one continuous chamber, the only obstructions in which would be the two piers between each gun chamber, which project $3\frac{1}{2}$ feet from the front.

The underside of the roof, ribs and girders and plating, should be covered with concrete or plaster to prevent the damp attacking them, and to counteract the effect of so much iron in condensing the moisture in the chamber. This can be effected with wooden joists fastened to the ribs, and lathed on the underside; the whole space between the laths and the underside of the curved roof plates should be filled with concrete or mortar as far as practicable.

T. B. C.

4.—IRON CASEMATE,

By Captain Schumann, Prussian Engineers.*

Translated by Lieut. T. Anstey, R.E.

Par. 1. The following designs, partly sketched, and partly still further followed out in constructions in Iron for purposes of Fortification, were conceived immediately after the question of iron plated ships began to excite a general interest; and as at the same time the repeated experiments made with rifled cannon against walls, shewed unmistakeably the danger to which the characteristic elements of the new Prussian system of defence were exposed, and the striving after a remedy for this was noticeable on all sides among the brothers of the sword, the author received an additional inducement to carry out his original ideas.

But, on the other hand, the newness of the circumstances—the insufficiency of the results obtained by the English and French experiments against constructions in iron for shipbuilding purposes,—the misfortune that mere mathematical calculations on the theory of impact (which has not yet been established by mechanical science), have little value,—throw just doubts on the value of his designs. As however similar proposals to those which the author formerly and especially worked at, have been made lately by others more competent, he seems to find in this agreëment of opinion an encouragement in thinking that he has not perhaps submitted quite worthless and useless material towards the perfection of the means of defence.

Par. 2. In the following pages it will be less a question of the way in which iron is daily more and more used in the other branches of architecture, than of the manner of its use as a means of defence. The use of iron will therefore more especially recommend itself to our notice in those portions of works which are immediately exposed to the fire of the enemy. If the use of iron for this purpose has up to this time not been customary, the reason of it may have existed less in the ignorance of the excellent qualities of the material than in the circumstance that the material used hitherto has corresponded to the means of attack; also, however, in the obstacles offered by the want of development in iron manufacture, and the corresponding cost of the material. The great progress made in artillery, and the astonishing development in iron manufacture happen at the same time, and if, as contrasted with the former, the value of the present means of defence seems to have considerably diminished, we are justified in looking about us for a newer and a better.

Iron offers a very considerably greater resistance to shot than stone or brickwork, earth remaining the body of the defence, as it should form the basis of

* Extracts only from Capt. Schumann's paper, sufficient to explain his principles, have been introduced here, on account of the length of the whole paper.

The paper was read by Capt. Schumann, at Chatham, in 1863, and as shewn in the opening remarks, embraced the whole subject of the use of iron in defences.—T. B. C.

every system of fortification. We should be in great embarrassment as to the value of iron as a means of defence against artillery, if the use of it in vessels of war had not already opened the way, and a long series of experiments assisted us to study the peculiarity of iron in its resistance to such powerful impact.

That which has been done up to the present time, and the information which the author has picked up, is principally derived from the system used in plating ships of war. In some of the proposals the elasticity of the materials of construction is taken advantage of. The thing to be considered is chiefly the placing in safety buildings which are already constructed and which are exposed, and more rarely the construction of new buildings.

Plating of ships can be only valuable in the application of iron to fortification, so far as concerns the power of resistance possessed by iron in the shape of plates, otherwise the relations are totally different.

Par. 3. Whilst on the one hand the ground-work of a ship has been hitherto of wood, on the other hand that of a land fortress has been of earth and stone or brickwork. The work in the one case is moveable, and in the other immoveable. A wooden ship can be plated only with iron; walls, on the contrary, can derive assistance from earth; in a ship the whole surface above water may be fired at, while in brick-work there is a possibility of exposing only certain parts.

The heaviest guns once placed in the battery of a ship are carried with ease by the waves; in a land-attack on a fort a 300-pdr. Armstrong gun is of no value.

Or if we were to allow that, with the help of a tramway, such a piece could be brought through the trenches into the battery, yet still it stands behind the same weak earth-shelter as the 12-pdr. The gun and its carriage are as perishable as those of the guns of the smallest calibre; and what an expense magazine will be necessary where 40 or 50 lbs. of powder are used at each shot!

Par. 4. Although the question of impenetrable plates for shipbuilding has not yet been brought to a close, yet it must be remembered that against a land fortress, guns over a certain calibre could not be mounted without probable damage to themselves. But if $4\frac{1}{2}$ to 6-in. plates on 2 feet of teak have, as a *moveable* target, been able to resist the fire of guns of the calibre of siege artillery hitherto used, would not such a plate attached to a wall, and offering for days together a target easy to be hit, be destroyed? Days would not be necessary, but indeed hours; and what difficulty there would be in attaching the plates! How is the wall to be relieved from the danger of crumbling, when with a $4\frac{1}{2}$-in. plate, the 2 feet of elastic teak suffered considerably from the fire of a 24-pdr.? *

How insufficient is the proposed construction of letting baulks into the walls and bolting the plates to them! Still a sufficiently large portion of the crushing would be transferred to the wall, and what continual and expensive repairs would be necessary if the wood between the iron and wall were to be suddenly destroyed! It is true that Captain Inglis's system, in its simplicity, would offer ample protection, and it does not require much skill to fasten three layers of strong 5-inch iron together, and to bolt them to a backing of wood. Yet one cannot

* There is some mistake in this; the 24-pdr. cannot be said to have produced any material injury on a target of that description.—T. B. C.

contemplate applying such a system of plating even to a small exposed surface, when the square foot would cost at least from 80 to 100 thalers.

The elasticity which it has been proposed to utilize would be of little use, because the velocity is too great, and too much time is required to impart motion during which the blow would have been long since expended. Besides which the cost of construction would greatly outweigh the saving made in using iron of less strength.

It results therefore that we must totally disregard the system of plating ships in constructing fortresses, and only regard the peculiar relations which obtain as regards these last.

Par. 5. The result of these considerations will be:

1. That iron, on account of its great cost, must only be used where the objectionable materials hitherto employed appear totally unfit for the purpose.

2. That there must be as small a mark as possible to the enemy's fire.

3. This mark must, if possible, never be exposed to the chance of a shot striking on it perpendicularly to the surface.

4. Earth must still be kept as the basis of defence as before.

Par. 6. No one would ever think of using such an expensive material as iron where wood and walls are sufficient.

To construct anything absolutely imperishable would be impossible. Besides which it would be a mistake to do so.

The strength of resistance should be in the proper proportion to means available for its destruction.

Keeping this rule in mind, we will at present willingly renounce the idea of escarp revetments plated with iron, such as Prion in his "Essai sur l'emploi du fer dans la Fortification" proposes, as well as that of making bomb-proof barracks of iron girders instead of the ordinary arches when situated behind ramparts, or in the interior of the town, and used merely as dwellings, and not intended for purposes of defence.

We should be perfectly justified in deriving assistance from iron in the case of a flanking battery situated in the prolongation of the ditch or of a Haxo exposed to direct fire, or a keep that may be demolished by means of indirect fire.

If in new works, the means of avoiding this evil have been found, yet to make the necessary alterations in those already built will be a very difficult task indeed; without being compelled to give up essential advantages through change of profile, displacement of earth, &c., it will be impossible to carry them out.

Par. 7. By making use of iron it is proposed to mitigate this evil, and in new works while still preserving the caponier system, to preserve the characteristic advantages of the system against indirect fire, which can be brought to perfection by rifled guns.

The proposal to be submitted, keeping in mind the rules laid down, consists chiefly in a system of iron bomb-proof girders, which, projecting out at right angles to the wall immediately above the embrasure, form a covering on which the earth may be moved forward, thus protecting the wall above the embrasure which may still be visible, so that the embrasure will be made in the earth, having a splay according to the nature of the defence required.

In most cases protection from indirect fire has to be considered, but also where exposed to direct fire the basis of construction is the same. Small portions of the building may also be strengthened in a corresponding manner.

The same principles may be carried out in new buildings. Whilst following out this principle in a few characteristic cases, the detail can be explained in the simplest and clearest manner; therefore farther on we will describe the construction of gun casemates acting as traverses; the mode of covering a one and two-storied caponier in a ditch; the covering of a one and two-storied keep; the representation of a "Montalembert" tower,* with a moveable iron cupola; and lastly a method of covering a 24-pdr. by means of plating.

EXTRACTS FROM THE THEORETICAL RESISTANCE OF BOMB-PROOF IRON COVERINGS.

Work done by a Shot, and Resistance of the Iron.

Par. 8. The work done by (or stored up in) a 50-pdr. shell filled with lead, at 75° elevation, is about 3,400 centners†—feet = 54,900 kilogrammes-metres. The diameter of the projectile, supposing it to be solid iron, is 30 centimetres.

A plate of the thickness e_o opposes to the penetration of a body of the circumference c a resistance = K. c. e_o.

The work done in penetrating to the depth e_o, is $T = \int_0^{e_o} Kc \times ede = \frac{1}{2} Kce_o^2$.

In rolled iron K = 3,000 kilogrammes per sq. centimetre, and if the diameter of the hole made = 30 centimetres, c = 0·94 metres. Then to find the thickness of a plate which will be just penetrated by a projectile having the above amount of work in it,

$$\tfrac{1}{2}\, 30{,}000{,}000 \times 0{\cdot}94 \times e_o^2 = 54900$$

$$\therefore e_o = 0{\cdot}062 \text{ metres } (= 2{\cdot}4 \text{ English in.})$$

It is here supposed that the ball strikes the plate perpendicularly; if it strikes it at an angle with the normal, then the thickness e of the plate will be diminished in the proportion of 1 $\times$ cos α; or $e = e_o \times \cos \alpha$.

Par. 9. It is supposed that the shot acts on the iron like a punch, and that the whole of the thickness of the plate resists it at once. In reality the shot strikes the plate on a small surface, and the middle part of the whole area struck is pressed through, and the circumference is afterwards sheared. Besides, the resistance of the iron ceases after a certain penetration, viz., when the circumference of the area punched has entirely separated from the rest of the plate, and there is only the friction to be overcome.

The penetration of a flat-headed projectile before the shearing action begins is $\frac{e}{n}$; the resistance up to this moment = K c' z, where z = the depth of

* This has been omitted from this paper, as it would carry the question beyond the limits proposed.—T. B. C.

† 1 Centner (Prussia) = 113·4 lbs. English.
1 Rhein Fuss = 1·03 feet ,,

(From Woolhouse's Weights and Measures).

penetration. The work of further penetration $= d\,T = c\,K\,z'$, and the whole work done $= c\int_0^{\frac{e}{n}} K\,z\,d\,z$, or $T = \frac{1}{2}\,c\,K'\left(\frac{e}{n}\right)^2$

By experiments in shearing $K' = 20{,}000$ kilogrammes per square centimetre, and $n = 7$.

Therefore $T = 200\,c\,e^2$ kilogrammes-centimetres, and equating that with the force of the shot, namely 5,490,000 kilogrammes-centimetres, c being 0·94 centimetres.

$$e = \sqrt{292} = 17{\cdot}1 \text{ centimetres } (= 6{\cdot}6 \text{ English inches}).$$

Therefore an iron plate 17 centimetres thick would be just penetrated.

The greatest resistance $= W = K'c\,\frac{e}{n} = 20{,}000\;c \times \frac{e}{7} = 2860\;c.e$ (kilogrammes); and taking $c = 0{\cdot}94$ metres and $e = 17$ centimetres, $W = 4{,}565{,}714$ kilogrammes. This is the measure of the resistance the plate offers to penetration.

Owing to the very short duration of the whole resistance, the backing of the plate cannot take it up, and the pressure upon the backing will be considerably less. There are no theoretical data for determining the relation between the pressure on the backing and the absolute pressure on the plate; therefore the strength of the backing can only be determined by experiment.

Par. 10. If we wish to replace the bomb-proof girders hitherto used by iron ones, we shall have to make these last of the same strength as the others; always supposing that the earthen covering is strong enough to destroy all the living effect of a ball, so that there will be no effect of impact on the supports. According to experience of what is bomb-proof up to this time, fir beams of 1 ft. = 31 centimetres, square, in section, laid one alongside the other, 9 feet = 282 centimetres long, and with an earthen covering 4 or 5 feet thick (1·26 to 1·57 metres) would suffice.

If for fracture $K = 700$ kilogrammes per square centimetre, then we obtain the breaking strength of the beams for 1·00 metres breadth from $\frac{1}{2}\,P\,l = 700\,\frac{1}{6}\,b\,h^2$.

$$\tfrac{1}{2}\,P.\,141 = 700 \times \tfrac{1}{6} \times 100 \times 961, \text{ and } P = 159{,}030 \text{ kilogrammes.}$$

In the case of the 50-pdr. shells filled with lead $2l = 6$ feet $= 188$ centimetres, therefore $P = 238{,}546$ kilogrammes*.

If the shell penetrates 4 feet = 1·25 metres, into the earthen covering, and if the resistance W, throughout the penetration, is equally great; we have $1{\cdot}25\;W = 54900$, from which $W = 43{,}920$ kilogrammes.

This, every moment that the resistance is protracted, works so near at length to the layer of beams, that it can only affect one of them.

The breaking strength of a beam is, as has already been stated, $\frac{1}{3} \times 238{,}546 = 79{,}515$ kilogrammes, therefore the above resistance is sufficient.

Par. 11. In absence of further data we will determine the dimensions of iron coverings, which, with a breadth of 1·0 metre, possess a capability of resisting fracture of 238,546 kilogrammes. As the modulus of work of the

* This value of l appears to have been determined from experiment, or otherwise arbitrarily; P therefore is here taken to represent the statical weight equivalent to the action of a 50-pdr. shell loaded with lead and fired at an elevation of 75°.—T. B. C.

limit of elasticity for rolled iron is at least five times greater than that for wood; while the co-efficient of fracture may be taken as only $\frac{30}{7} \doteqdot 4{\cdot}3$ times greater; therefore we shall be right according to the above supposition, for the effect also of a living force.

Railway Iron.

Par. 12. If U represent the moment of inertia, and V the distance of the outer fibres from the neutral axis, then we have for the profile of Bavarian rails;

$\frac{U}{V} = 122$ centimetres³, therefore for the greatest moment of the load,

$M = \frac{1}{2} Pl = 3000^{*} \times 122 = 366000$ kilogrammes-centimetres;

and when $P = 2385{\cdot}5\ b$, if b represent the breadth of the rails in centimetres.

$$bl = 2 \times \frac{366000}{2385{\cdot}5} = 307 \text{ centimetres.}$$

If we take 12 feet interval or bearing as a sufficient maximum, then,

$$l = 190 \text{ centimetres}$$

$$\text{Therefore } b = \frac{307}{190} = 1{\cdot}62 \text{ centimetre.}$$

The distance apart of the rails should therefore be 1·62 centimetres.

But they cannot rest close alongside one another as their base is 10 centimetres, therefore $\frac{10}{1{\cdot}62} = 6{\cdot}2$ layers, must be put on one another.†

Weight with 3·8 metres width or bearing, and 1 metre breadth :—

1 bar 4·2 metres long weighs $4{\cdot}2 \times 38 = 160$ kilogrammes; therefore 10 placed side by side = 1600, and 6 layers of them = 9600 kilogrammes.

To ensure them as far as possible against a shock, they may be covered with layers of short pieces of wood placed obliquely, and they can be protected by tarred paper from water filtering through the earth, in the same way as sod roofs are protected.

Par. 13. *Double* T-*Iron.*—The section generally used for the long baulks of railway carriages has 234 millimetres height, 90 millimetres breadth, (of flange), and 13 millimetres thickness of metal; therefore $\frac{U}{V} = 328^3$ c.m., and $U = 50{\cdot}41$ c.m., and therefore when the supports rest one on another,

$$P = 9 \text{ c.m.} \times 2385{\cdot}5 = 21470 \text{ kilogrammes.}$$

* This 3000 is the resistance of the iron in kilogrammes per square centimetre.—T. B. C.

† This necessity appears to invalidate all the previous calculation for these rails.—T. B. C.

Therefore $21470 \times l = 2 \times 3000 \times 328 = 1{,}968{,}000$, and $l = 91{\cdot}7$.
For another width l, and distance apart of iron b, both being measured in centimetres,

$$bl = 2 \times \frac{3000 \times 328}{2385{\cdot}5} = 825$$

$$\text{when } l = 190,\ b = 4{\cdot}34, \text{ therefore,}$$

$$\frac{9}{4{\cdot}34} = 2 \text{ layers one on another.}$$

For the weight of 1 metre breadth, and 2 layers one on the other :—

$$4{\cdot}2 \text{ metres} \times 38 \times \frac{100}{9} \times 2 = 3556 \text{ kilogrammes.}$$

These dimensions are so large that it is almost impossible to use them in practice on account of the cost.

Gun Chambers with Bomb-proof Covering made of Girders.

Par 14. In gun casemates acting as traverses, as they have hitherto been made, the part of the wall above the embrasure (increased by the arch of the covering) is exposed to fire.

The large traverses on the capital of the terrepleins of bastions will also suffer by the perfecting of the system of indirect fire.

If their cordon be compared in its command with that of the wall in front, it will be seen that it is possible almost every time to hit them without having to use too great an angle of elevation.

At the same time, the gun used in the traverse (supposing it to be hollow) can only be a howitzer which can be fired only with great elevation, and it may happen that the principal object to be aimed at, viz., the lodgments on the glacis of collateral works, may be too near for good practice.

By using an iron covering the advantage to be gained is, that above the muzzle of the gun the smallest possible mark, and at the same time that most capable of resisting the enemy's fire, will be exposed.

If this advantage is gained on the one hand by the small thickness of the girders compared to any vaulted roof, yet at the same time if the objectionable genouillère were used, some portion would still offer a target to the enemy. For this reason the casemate is adapted with a "Liel" gun carriage, and 4 ft. 7 in. is allowed for the height of the genouillère, at the same time the roof is lowered so that the under edge of the girders which compose it shall be on a level with the top of the embrasure, and they are laid with such a slope upwards to the rear, that when using a 24-pdr. rifled gun at an angle of depression of 5°, there may still be 8 inches space above the vent for laying the gun.

Gun Chamber, with Iron Roof, for Three Guns.

Par. 15. Pl. 6, fig. 1. This is 24 ft. wide and 25 ft. deep; the dimensions being however altered according to circumstances. Three guns are able to fire in different directions at once, and two of them at the same object at once, thereby making the field commanded by the casemate very large.

As regards the detailed construction, the roof is made of T-iron 13 in. deep, at 2 ft. central intervals. In the curved portion, the girders are not arranged as radii, but as tie-pieces, as in fig. 1, on account of the greater facility afforded in fixing them, because, if arranged as radii, a hollow iron column, of at least 2 feet diameter, would be necessary to support the ends of the girders. This column would also be in the way of the working of the gun placed on the capital.

Between the girders, and resting on the lower flanges, are placed curved iron plates having a curve of 4 inches in the 2 feet, and on these plates concrete of the best material is rammed, the layer extending 1 foot over the upper flange of the girder.

In this manner a number of small bomb-proof arches are made which correspond to an arch, which, in a span of 6 feet, is 2 feet thick, and therefore bomb-proof with even a small quantity of earth on it.

The size of the girders is sufficient according to theoretical calculation. As a high mass of earth has disadvantages, the thickness has been lessened to 5 or 6 ft., and the arches of concrete will fully compensate this decrease in thickness. A concrete of hydraulic mortar has been recommended, for if the arches were made of brick, it is to be feared that, from the effect of shot striking particularly the ends of the girders, the mortar would be loosened, although the curved plates would prevent it falling out altogether.

Par. 16. From the theoretical calculations, instead of a support for each girder from beneath, a support from above has been used, to which the girders are attached by means of rivets of the necessary dimensions.

The example of the gun chamber will show why this arrangement is necessary. If support from below were made use of, the whole roof would have to be raised by the thickness of the supporting gear, which would expose this last to destruction from shot entering the top of the embrasure; therefore a support from above has been constructed which derives protection from the mass of concrete.

When only indirect fire has to be feared, it will be a saving only to plate the ends of the girders, and not to allow the plates to extend over the concrete.

In this case, the objection might be made that the covering is not sufficiently protected; in the case of the construction that has been adopted however, there is no fear of this.

Par. 17. There are stretched between every two girders two plates the same height as the girders, and $\frac{1}{2}$ inch thick; the intimate connection of which, with the middle rib of the girder, is ensured by means of flanges and ten rivets; above and below every girder there runs a flat iron which is fastened to the vertical plate before-mentioned by means of two pieces of angle-iron. The weight and strength of the plates, as well as the sum of the sections of the rivets, guarantee an unalterable connexion.

The bomb-proof girders lie in such a manner that the one on each side is 2 ft. from the one over the middle of the embrasure. The neck of the embrasure is 21 in. wide, so that the two girders on each side are 18 in. from it.

Par. 18. The three girders are protected by a 5-inch rolled iron plate, at an inclination to the horizontal of 30°. The ends of the girders, which are not armour-plated, are protected by the ground in front of the merlon.

A shot coming with an angle of depression of 5°, will strike the plate at an angle of 35°; and as the angle-iron, by means of which these plates are fastened to the girders, makes the whole plate 6 inches thick, therefore from experiments which have been made, the plate is fully capable of resisting with success. The mass of concrete behind, which, although liable to crumble from the vibration, is not able to fall out, will always make a sufficient backing.

Where the plate abuts against the end of the girder, the resistance will be quite as great as that of the targets and sections of vessels that have been hitherto made. It would therefore be necessary for an enemy to hurl the whole system, together with its weight of earth, to the ground, in order to destroy it.

Par. 19. Pl. 6, fig. 4. The covering is supported in the following manner. The supports consist of massive 6-inch wrought iron columns, and the connexion with the girders is explained in Fig. 4, Pl. 6.

The girders do not rest on the walls but on these iron columns.

The centre supports, which are not exposed to fire, consist of a hollow construction of iron plates; two vertical plates are stiffened by having angle-iron riveted to them, and plates stretched between them.

Between the vertical angle plates which are ½ inch apart, an iron plate is riveted in the upper part; this at the same time serves instead of a support to the above-mentioned plates, and the result is an absolutely safe connexion between the bomb-proof covering and the supports.

The destruction of this would be only possible when the armour plates are broken, and the 4 feet of concrete and the plates ½ inch thick, with their 1-foot covering of concrete, are pierced by the shot.

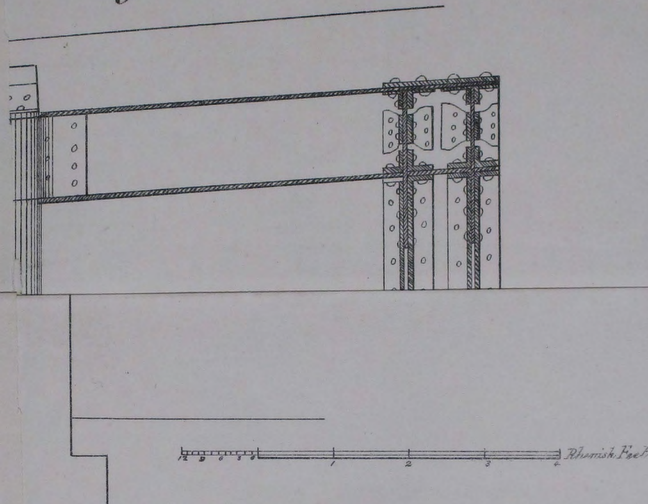
Masking the embrasure and making use of a support from beneath would immediately remedy the evil; as the girders which may have been broken between two of the supports, can, with the help of the upper and lower flanges, which may be taken as imperishable, support their own weight very well, but would not be bomb-proof.

Par. 20. The last girder before the curve commences has two supports, in order not to hinder the working of the gun on the capital, at the same time giving it additional strength to carry the tie-beams which cover the curved portion.

In the design the outer wall is carried up to the level of the girders; by doing this the embrasures have all the well known disadvantages consequent on having them made in brick or stone-work.

Perhaps it would be an essential advantage if the wall were only carried up as far as the genouillère (4 ft. 7 in.) and 3 feet thick, leaving the space between the top of the wall and the girders quite open. By that means the embrasure might be placed wherever necessary, as in the case of an open breastwork, always provided that the armour plates run along the whole length instead of only over the embrasures.

Fig. 4



Par. 21. The weak points are at the outside gabions of the embrasure, and indeed the gabions in the cheeks which are so easily displaced might be dispensed with, using a very sloping scarp instead; if use is made of rails in lengths of 6 feet, laid against a girder to receive the shock, placing some above against the armour plates as well, a far securer wall than one of brickwork would be thereby obtained; as 6 or 8 feet of earth before the $4\frac{1}{2}$-inch thick layer of rails would be quite enough.

The forepart of the crown of the breastwork would be lowered so much farther as to allow of a depression of 5° for the sole of the embrasure.

If one embrasure is rendered incapable of firing out of, it would be masked by sand bags, while rails are being laid across; by which means the genouillère may be made as thought best. If the embrasure is required to be still stronger, railway carriage wheels laid one on the other might be placed in the neck of the embrasure, made fast by driving piles between the spokes; they are now made of homogeneous iron and are often bound with cast-steel. Their curved form and thickness would enable them to last for a long time.

As the diameter of the wheels in general is 3 feet, there would only remain 3 feet more for the neck of the embrasure.

Par. 22. Such a casemate would allow of being fired out of in any manner, and would command an extent of field but little less than that commanded from an open wall.

If these last arrangements are only made when placing the fortress on a war footing, or even during an attack, the whole casemate might be made for 8,000 fls.* (£686); if three guns are taken as firing at the same time, it would only be 2,700 fls. for each, which is not much more than the cost of an ordinary casemate of brickwork for one gun.

5.—Iron Embrasures in Earth in Front of Existing Casemates.

Par. 1. The manner of covering gun chambers lays the foundation for the principles to be followed in protecting works which have been already constructed.

Pl. 7. Figs. 1 & 2. Plate 7, figs. 1 and 2, show a caponier in a ditch which is so situated as to be in danger of destruction from the high ground in front of it, in the prolongation of the ditch; the results of which would be, not only that the flank fire would be destroyed, but a breach made as well.

If, as in the case of the gun chamber already described, a system of iron girders be brought to bear immediately over the embrasures, projecting so that the covering of earth might be moved forward on the platform so formed; at the same time, piling earth up against the part of the wall below the sole of the embrasure; the embrasures might be prolonged in the earth under the platform above, by means of gabions, at the expense of the loop-holes which might have before existed in the wall.

The ends of the girders in the wall are riveted to a T-iron, which acts as a foundation and receives the shock from shot striking their outer ends. The connexion between the girders themselves is formed of iron plates and armour plating, as in the case of the covering of the gun chamber.

* The German florin is about $20\frac{1}{2}$ pence English.

Thus a shock on the outer end against the armour plate would be communicated to the whole platform, and set the whole mass in motion, before it could affect the wall behind.

Then, however, all the work done by the shot would be expended. If, notwithstanding, an evil effect is still to be feared, a space of 6 inches might be left between the abutting girder behind and the wall, the space being filled in with fine sand.

Par. 2. The supports for this covering are made of massive 6-inch iron, with cast-iron shoes let into strong stone. They are immoveably fastened to the girders, and are beside that protected by the earth in the merlons; they are stiffened by the earth between them and the front wall, and as the line of fire can be but slightly inclined to the face of the caponier, the breadth of the foundation wall will be sufficient to prevent their being moved laterally.

The increased thickness of the mass of earth on the caponier might be very well turned to account as a position for musketry, which must be very annoying against the embrasures of a counter-battery. With this small mark the battery will not be able to be destroyed by indirect fire, besides which it will not be necessary to unmask the embrasures.

But against a counter-battery, the embrasures so constructed would be more serviceable than those made in a wall.

Par. 3. As, however, in the case of low flanking fire along the bottom of the ditch, a very small lateral range will answer the purpose intended, the embrasures might be constructed in the following manner.

A number of railway bars are bent into rings of different diameters, and by means of iron plate half an inch or an inch thick, made into a funnel. If instead of using the bent rails, the tires of railway wheels are taken, a capital material, either homogeneous iron or cast-steel, is obtained for this species of construction.

The shot which strike the cheeks will do so sufficiently obliquely to glance off in most cases, and be prevented by the middle and hindmost rings (which project) from entering the embrasure, in a similar manner to the loop-holes built in brick-work against musketry fire.

But even if shot do get through, a great many will be necessary to render the embrasure unfit for use. The hood cannot be destroyed at all, and in the lower part, for economy's sake, the plating might be omitted altogether.

If such an embrasure were fitted into the parapet instead of those of earth, which are so easily destroyed, it would be found, that on account of the thickness of the parapet, the lateral range of 30° would make the outer opening so large as to render the construction impracticable.

Par. 4. If, however, at the place where the embrasure is to be constructed, the interior slope for a sufficient length be strengthened by railway iron piled up, having the necessary backing of props and stays, the top of the parapet might be lessened to 8 and even 6 feet thick. Then by breaking the tires and pressing them into the form of a basket handle, an embrasure having the necessary lateral and vertical range might be constructed. The wheel tires are usually from 3 to 6 feet in diameter.

Par. 5. If the flanking battery consists of two stories, and it is not intended to give up the lower one by piling earth in front of it,

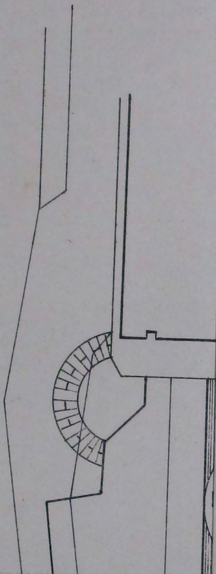
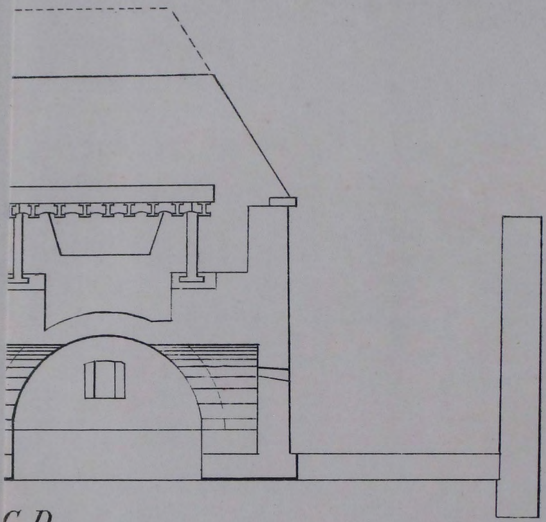


PLATE 8



C D

Pl. 8, figs. 1, 2, & 3. a construction similar to that shown in figs. 1, 2, and 3, Pl. 8, must be resorted to. The lower story, being the gun casemate, will be treated in a similar manner to those already described, and it will form the foundation for the upper bomb-proof covering. As both layers of bomb-proof girders are exposed to direct fire, their ends must be protected by armour plates.

The supports are protected by the earth in the merlons. The newly constructed casemates have a breadth of 16 feet, and a depth of 12 feet, and have sufficient space for the lightest guns, for the purpose of sweeping the ditch.

By raising the gun as high in the casemate as possible, and firing immediately beneath the roof and parallel to it, the battery on the crowning of the glacis may be hit.

The disproportionately strong layer in the middle is made in order to give sufficient strength to the supports on the upper floor, as the whole weight of the upper covering will come on these if the span of the arches is made larger.

In order to prevent the whole structure from tipping over to the front, when a shell falls on the outer edge of the lower bomb-proof, the longitudinal girders behind are fastened by a number of anchors, securely fixed in the foundation of the casemate. By making a platform on the top, the counter-battery will be under the fire of three stories; and as the embrasures on the top will be made of earth, they can be easily repaired when knocked to pieces.

Considering the small space in front of the salient of a bastion it will be impossible to construct a counter-battery under such an overwhelming fire.

6.—Iron Moveable Chamber for One Gun.

Par. 1. Apart from the fact that masonry is exposed to greater danger through the introduction of rifled guns, it is not difficult to prove that the defence gains more by them than the attack. The effectiveness of small calibres against works of attack as formerly constructed was of no account; and the performances of the 6-pdr., the moveability of the artillery of defence, together with the effectiveness of the same, are greatly increased.

By means of the guns of heavy calibre, the influence of the collateral works is far more felt, and compels the attack to be extended in proportion. These two principal advantages justify the belief that the best defence against rifled guns, is rifled guns. As, however, the besieger possesses the inestimable advantage of being able to forward his supplies at will, we must consider how we can place as securely as possible the costly guns, and particularly those of large calibre, which cannot be so easily moved. We have sufficiently explained of what little service in this respect are the hollow traverses, &c., and how they may be only partially improved by means of iron, which gave rise to the idea of the iron cupola. It is, however, not always possible to construct a cupola tower; it would be of the greatest importance, if, instead of the gun chambers, we could make a construction which, while offering sufficient security, would

Pl. 9. allow of the guns performing the utmost which could be expected. Such an arrangement we have endeavoured to show in Pl. 9.

Par. 2. Fig. 1.—Shows a vertical longitudinal section with a side view and framing.
- „ 2.—A front view.
- „ 3.—Back view of the inner parts; the door and back wall being taken away.
- „ 4.—Back view with door and wall.
- „ 5.—Plan, the rollers being shown.
- „ 6.—Horizontal section showing plan of gun platform and floor for the men.
- „ 7.—Vertical cross-section of the frame and floor.
- „ 8.—Detail for making the "chamber."
- „ 9.—Shows how it can be moved to a considerable distance.

The vertical movement of the platform renders it possible to reduce the embrasure of the gun chamber, and that in the parapet, to a minimum, by an arrangement shown in figs. 1, 3, and 6, consisting of an endless screw, allowing the platform to be moved smoothly up and down.

The connection of the endless screw together is shown by the dotted lines in fig. 6; also the point is marked, where, by means of a wheel and axle, the endless screw is made to revolve.

To move the chamber horizontally about its central axis, beneath the mouth of the gun, by means of a block of cast-iron and "anchor screws," fastened to a stretcher, strong supports and very strong iron bands on them are used, resting on three legs, of which one of the hind ones is provided with a wheel and axle, and admits of an easy and accurate side movement.

Par. 3. The gun, with its bullet proof covering, has a lateral range of 120°, and 20° vertical, for high elevations; the gun is always entirely protected by the front wall. For 5° depression a cutting 1 foot deep will be necessary.

The opening of the embrasure affords only just sufficient room for the gun to run back and the gunner to aim. Three men are required to serve the gun, as the raising the platform and side movement require only one man, and the gun runs forward of itself. A common earthen traverse is sufficient to cover it from enfilade fire.

The chamber itself is capable of holding 30 or 35 charges. The railway is built on cross and longitudinal sleepers, and can be easily repaired if damaged by shells.

A gun in such a position would in all probability retain its advantages against a great many of those of the besieger.

The method of breech-loading permits of the front part being funnel shaped, and thus the object to be aimed at will be hardly any bigger than the muzzle of the gun.

If the side of the funnel part be plated 3 inches thick, it will be shot-proof.

Par. 4. It is too small to be struck by mortars, but even in this case the strength is sufficient to resist shells of the largest calibre.

The chamber permits the artillerymen also to remain in it to the last moment, when the enemy are climbing the parapet. The bullet-proof door renders them perfectly secure, and as there are three loop-holes in it, as well as on each side,

Plate 9.

BACK VIEW.

WITHOUT DOOR.

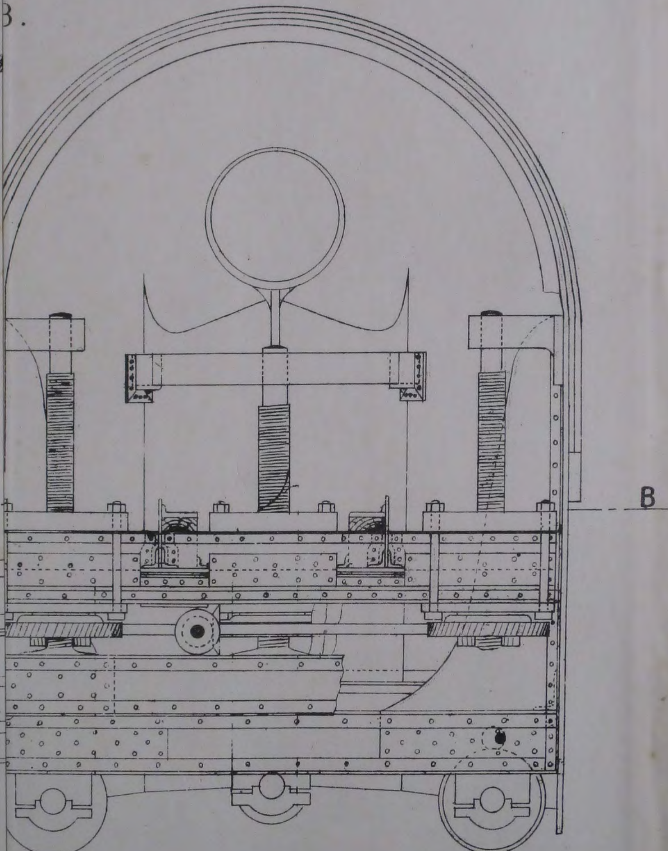
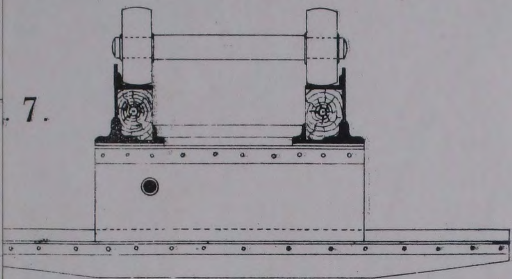
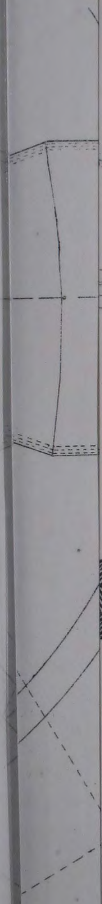


Plate 9.
(continued)

SECTION OF RAISING PLATFORM.



7.



SECTION OF ARMOUR PLATES.

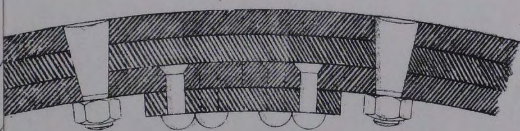
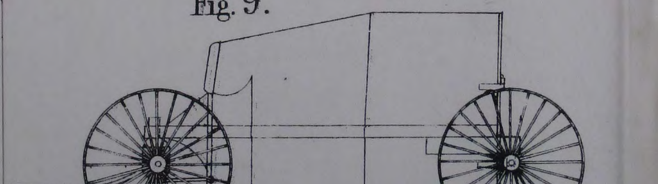


Fig. 9.



the men inside can sweep the rampart with short guns or revolvers, and wait till the reserve force drives the enemy from the parapet.

A lodgment on the earthwork is hardly to be supposed possible, if even one of these guns be placed in position, when it is considered that the damage done by sharpshooters to ordinary embrasures is here reduced to a minimum.

When loading, or when the gun is not being fired, it can be turned towards the traverse, thus rendering an especial embrasure unnecessary.

The whole weight of the chamber is estimated at 23·2 tons, and as shown in fig. 9, it can be transported even up slight inclines.

This circumstance is of importance when the front of attack is not decided, and the cost of constructing many of them would be too great. We require only high and sufficiently strong wheels, having broad tires to be held in readiness, their fastening to axles being visible from the drawing.

The transport will have to be undertaken when putting the fortress on a war footing, to oppose the first and strong attack.

Windlasses will naturally be required instead of horses, for dragging them up the ramps. The cost taken at a round sum according to the price of iron is 8,200 to 8,600 fls. (£703 to £737).

7.—TABLE OF APPROXIMATE ESTIMATES.

OF

IRON CASEMATES.

		£
Capt. Inglis's shield to resist heavy guns (C.P., Vol. XI., p. 209)	per gun.	300 to 500
Capt. Inglis; Iron front to escarps (C.P., Vol. XI, p. 212),	per foot sup.	2 to 5
Capt. Inglis; Iron fort for land defences (C.P., Vol. XI, p. 216)	per gun.	1300
Capt. Inglis; Iron fort for sea defences	per gun.	1600 to 1800
Masonry casemate, with iron front on Capt. Inglis's plan. . (to resist heavy guns) Est. No. 1.	per gun.	1200
Iron casemate (to resist heavy guns) on Lieut. English's plan. (for 2 guns) Est. No. 2.	per gun.	3100
Iron casemate; laminated plan (to resist heavy guns) . . . by Lieut. Colonel Collinson, Est. No. 3.	per gun.	1720
Capt. Schumann's cover for embrasure (to resist siege guns) . including masonry, in a 3-gun casemate.	per gun.	230
Capt. Schumann's iron cell (to resist siege guns)	per gun.	700
Capt. Schumann's iron redoubt (to resist siege guns) for 4 guns,	per gun.	1300
Capt. Coles's cupola (to resist heavy guns), for 2 guns . . .	per gun.	2100

No. 1.

ESTIMATE OF MASONRY CASEMATE WITH IRON FRONT, AS PROPOSED BY CAPT. INGLIS, R.E.

Excavator's Work.

	Prices. £ s. d.	£ s. d.	£ s. d.
$53\frac{9}{27}$ yds. cube ground dug and thrown out and removed from the site sufficiently far to provide for the work being carried on.	⅌ yd. 0 0 6	1 7 0	
200 yds. cube earth (covering for the arches) wheeled to a height of say 20 feet, and consolidated	0 0 8	6 13 4	8 0 4

Bricklayer's Work.

	£ s. d.	£ s. d.	£ s. d.
$53\frac{9}{27}$ yds. cube concrete, composed of 4 parts screened gravel, 1 clean sharp sand, and 1 fresh well-burnt stout lime properly mixed	0 8 6	22 13 4	
17 rods cube of portions of two half-piers in rear of stone-work arches, &c., &c., with square piers at rear of casemate . . .	⅌ rod. 12 0 0	204 0 0	226 13 4

Mason's Work.

	£ s. d.	£ s. d.	£ s. d.
368 ft. cube stone set in for fronts of piers (half).	⅌ ft. cube. 0 4 0	73 12 0	
394 ft. cube arch (hood-shaped)	0 4 0	78 16 0	
200 ft. cube two half-spandrils	0 4 0	40 0 0	192 8 0

Iron Plating, &c.

Tons	cwt.	qrs.		⅌ ton. £ s. d.	£ s. d.	£ s. d.
7	15	3	Exterior vertical plates. . .	36 0 0	280 7 0	
5	13	3	Horizontal plates.	36 0 0	204 15 0	
1	12	2	Vertical bars (4)	36 0 0	58 10 0	
0	19	3	Top bar (1)	36 0 0	35 11 0	
1	1	2	Bottom bar (1)	36 0 0	38 5 0	617 8 0
0	19	1	Bolts and nuts complete (42).	30 0 0	28 17 6	
0	5	2	Rivets 1⅛in. diameter (188).	30 0 0	8 5 0	37 2 6
1	7	11	Supports framed of 1-in. plate and angle-iron riveted . .	18 0 0	24 8 3	
0	3	0	Plates in rear of ditto (2). .	18 0 0	2 14 0	
1	5	2	Bars in ground under ditto (2)	18 0 0	22 14 6	
0	16	1	Bar built into brick-work at ends (1)	18 0 0	14 12 6	64 9 3
						718 19 9

SUMMARY.

	£	s.	d.
Excavator	8	0	4
Bricklayer	226	13	4
Mason	192	8	0
Iron-work	718	19	9
Total estimated cost .	1,146	1	7

No. 2.

IRON CASEMATE DESIGNED BY LIEUT. ENGLISH, R.E.

BRICKLAYER'S WORK.

	Prices. £ s. d.	£ s. d.	£ s. d.
	₶ yd. cube.		
$7\frac{7}{27}$ yds. cube concrete: 6 parts gravel, 1 part sand, 1 part lime.	0 8 6	3 1 8	
	₶ yd. super.		
96 yds. superficial Pyrymont Seyssel Asphalte, best quality.	0 9 0	43 4 0	46 5 8

CARPENTER'S WORK.

	₶ ft. cube.		
722 ft. cube teak, fixed and framed. . . .	0 7 0		252 14 0

SMITH'S WORK.

Tons cwt.		₶ ton.		
345 14	Rolled iron	15 0 0	5185 10 0	
20 3	Forged iron	30 0 0	604 10 0	
32 feet run 6-in. round bar		0 9 0	14 8 0	
84 feet run 5-in. do.		0 6 0	25 4 0	
230 feet run 1-in. rivet iron		0 4 0	3 16 8	
10 cwt. nuts, 10 lbs.		1 0 0	10 0 0	5843 8 8

	₶ yd. super.		
$5\frac{3}{4}$ yds. superficial 4 coats best oil common colours.	0 0 5	0 2 $4\frac{1}{4}$	
473 yds. superficial 4 coats best oil best colours.	0 0 6	11 16 6	11 18 10

SUMMARY.

	£	s.	d.
Bricklayer	46	5	8
Carpenter	252	14	0
Smith.	5843	8	8
Painter	11	18	10
Total estimated cost. .	6154	7	2

No. 3.

LAMINATED IRON CASEMATE DESIGNED BY LIEUT. COL. COLLINSON, R.E.

Bricklayer's Work.

	Prices. £ s. d.	£ s. d.	£ s. d.
$11\frac{7}{27}$ yds. cube concrete, composed of 4 parts gravel, 1 fresh water sand, and 1 fresh burnt hydraulic lime (for flooring) . . .	₰ yd. cube. 0 8 6	4 15 8	
$39\frac{26}{27}$ yds. do. do. (top).	0 8 6	16 19 8	21 15 4

Mason's Work.

	₰ ft. cube.		
266·3 feet cube stone, &c., in cornice over shield (for one gun portion as above) . .	0 4 0	53 5 0	
324 feet cube stone in piers, &c., at rear of casemates	Do.	64 16 0	118 1 0

Smith's Work.

Tons	cwt.	qrs.				
8	8	1	Wrought iron in outer shield composed of twenty-three 1-in. angle plates, 15 ft. 4 in. by 1 ft. 4 in. wide	₰ ton. 18 0 0	151 8 6	
23	2	3	Do. do. ninety-two 1-in. plates, 15 ft. 4 in. long by 11 in. wide	. . . .	416 9 6	
					567 18 0	
1	11	0	Deduct for embrasure		27 18 0	540 0 0
0	9	3	Embrasure plates (shield)		8 15 6	
3	7	2	Angle plates, &c., for piers (2)		60 15 0	
3	11	3	Do. do. for posts (2)		64 11 6	
5	15	1	Girders (main) for roof (2); Packing for ditto	. . . .	103 14 6	
15	12	2	Curved ribs for ditto (8)		281 5 0	
3	18	0	Straght ditto for ditto (8)		70 4 0	
5	15	0	Arched plating for ditto		103 10 0	
0	17	3	Brackets for piers and posts (8) of sizes.	. . . .	15 19 6	
3	0	2	Longitudinal girders in floor (2)		54 9 0	
12	7	2	Transverse ditto (4)		222 15 0	
2	6	3	Posts at rear of casemate.		46 16 0	1032 15 0
						£1572 15 0

SUMMARY.

	£ s. d.
Bricklayer	21 15 4
Mason	118 1 0
Smith	1572 15 0
Total estimated cost . .	1712 11 4

DISCUSSION.

A portion of the foregoing Paper having been read by Lieut. Col. Collinson, R.E., at an Occasional Meeting of the Royal Engineers, on the 26th June, 1865, the following discussion ensued,

MAJOR GENERAL SIR F. ABBOTT, C.B., was in the Chair.

MAJOR PASLEY: I am not quite sure whether I quite understood Colonel Collinson's meaning with regard to the comparative strength of plates of iron. I understood him to say it was an absolute theory that the strength of the plate was in fact directly in proportion to its cubic contents, the length multiplied by the breadth, and by the thickness. Is that the case? For instance, taking what Colonel Collinson mentioned as the thickness necessary to resist small arms, 1 inch; supposing a plate 1 inch thick and 1 foot square, is capable of resisting small arms, according to that rule a plate 4 feet square and $\frac{1}{16}$th of an inch in thickness, would be capable of resisting small arms. I wish to understand correctly what Colonel Collinson's rule is, as I think I must have misunderstood him.

LIEUT. COLONEL COLLINSON: As I said, these are purely theoretical considerations, subject to a very considerable modification in practice. If you are dealing with the same iron projectile, and with plates of the same general form and variable area, and variable thickness, then I think it is quite true that the resistance of any plate is as the length multiplied by the breadth, multiplied by the thickness, theoretically, although, as I said in that case, the real resistance is modified by the actual velocity of the shot, according to some law of which we have no data at present, and it is that velocity of the shot that would affect the question in dealing with very thin plates. If you were firing at a very thin plate with a leaden ball, if the velocity was exceedingly high, the plate would be broken by punching a hole in it, and then the resistance, as I said before, would be to some extent as the square of the thickness. But if the velocity of the bullet was small, then it would be broken by deflection. Between those two cases, we may say, are the two extremes of breaking a plate, either by deflection or by punching a hole in it, and we have no laws to tell us where to apply the one and where the other at present. We can only give our own opinion and judgment.

LIEUT. COL. JERVOIS: If I understand Colonel Collinson aright, his theory would lead to the conclusion that a plate 10 ft. square and 3 in. thick, the content of which would be 25 cubic feet, would give the same resistance as a plate 5 ft. long, 2 ft. broad, and 30 in. thick, the content of which would also be 25 cubic feet. Obviously, this could not be the case in practice.

COLONEL OWEN: We have been told that the resistance of a plate to a shot varies as the length multiplied by the breadth multiplied by the thickness, and that therefore a square plate will offer a much greater resistance than any other shape. I have before me, I imagine, two plates, one 4 feet by 1 foot, the other 2 feet by 2 feet, each of the same thickness, then their cubic contents would be the same. Then, according to this theory, their resistance would be the same, and still we are told that the one 2 feet by 2 feet would offer more resistance than the one 4 feet by 1 foot. That is what I do not quite understand.

Lieut. Colonel Collinson: It is quite true; according to theory the same mechanical effect is required to break the two plates, exactly the same, by deflection. But it is also quite true, by theory, that the plate which is 4 feet long and 1 foot broad, would go through more, as the cube of the bearing; that is to say, it would go through double the amount of deflection in being broken, and therefore the slightest imperfection in the plate and material would be certain to break it before the other one was broken; and that is the way in which I suppose all the long plates are really broken. That is to say, they go through so much deflection, before they come to the breaking point, that the imperfection of material comes into play.

Lieut. Col. Jervois: I think the conversation that has taken place with reference to the theory respecting the strength of iron plates, proves the truth of Colonel Collinson's remarks, namely, that as yet we have not sufficient experience to enable us to form a correct theory upon the subject; therefore, we had probably better rely upon our practical experience in considering the question. I do not propose to follow Colonel Collinson through the several remarks he has made this evening, but I wish to make one or two observations with reference to the iron casemate proposed by him, and shewn in the drawing on the board. The special point to be considered in it, is the external armour. It consists of an iron skin—I forget what thickness.

Lieut. Col. Collinson: An inch.

Lieut. Col. Jervois: Upon that are riveted angle-irons, 4 in. in depth and 12 in. in length; between the angle-irons, and riveted to them, three 1-in. plates are placed horizontally, with their edges outwards. The rest is an ordinary construction with a roof of iron girders and buckled plates. We have already constructed some bomb-proof roofs on this principle. As regards the iron wall of the fort, I think there is no experience to show that the structure, which is only 2 in. thick, and which consists chiefly of iron plates about 10 in. broad and 1 in. thick, placed over one another, would resist a 220-lb. shot. My belief is that a 220-lb. shot would go right through it.

Lieut. Col. Collinson: It was not calculated, certainly, for 220-lb. shot.

Lieut. Col. Jervois: Then I think it must be admitted that it would not be a desirable structure for a sea casemate. We have already at Shoeburyness a shield, the interior of which consists of laminated plates piled one over another. We have, however, in front of them a 4-in. plate; we have behind them a backing and another skin, the whole being bolted through. We have not yet tried the power of resistance of this target to a 220-lb. shot, and I am not sure whether it will resist a shot of that weight, fired with the service charge from a $12\frac{1}{2}$-ton gun. If it is necessary to add a 4-in. plate outside the laminated plates, the structure proposed by Lieut. Col. Collinson of course will not do. It should be observed that the target I refer to is merely for a shield round the embrazure, whereas Col. Collinson's proposal is intended for the whole face of the work. I do not know that there is anything more to say about this proposal, except with regard to the question of expense. Col. Collinson estimates the cost of his casemate at £1,700. He omitted, however, to mention that the guns are placed only 16 ft. apart; but if we allow 24 ft. as the distance apart for large modern guns, and which the Artillery authorities have stated to be necessary in a granite work with iron shields, half as much again must be added to the length of the structure. I think Artillery authorities would rather reduce the number of guns than put them only 16 ft. apart. If, then, one-half is added to the length of the work, and the necessary additional thickness of armour (the expense of which cannot be taken at less than about £6 10s. per superficial foot) is taken into account, it will be seen that the estimate of £1,700 will be very much increased. It is further to be remarked that in Col. Collinson's casemate there is no provision made for the general completion of the work, and there is no arrangement for making it secure against assault; a large further addition on these accounts must be made to the estimated cost of this structure. I have gone into the question a great many times, to see whether iron structures, capable of resisting modern artillery, could be made for the sums that are available for our casemated sea-works, and I have found that whatever way the case is put, an iron casemate will be found very much more expensive than one of granite with iron shields. No doubt an iron structure *can* be made so as to resist anything that can be brought against it, but that is not the whole question; it must be considered what is, on the whole, the best mode of spending a certain sum of money upon casemated sea-batteries. Different people will, of course, differ on that point. I do not hesitate to state my belief at the present time that the casemated work of solid masonry with iron shields will give what is required—*i.e.*, sufficient strength for sea batteries. It does not follow at all because the masonry can be knocked down by continued firing from a land battery that it will therefore be ineffective for its purpose. Ships fire at random: it is a great chance whether more than two or three shots hit in the same place; I believe that the casemate at Shoeburyness underwent as great a trial as it is ever likely to undergo in any action, supposing no more powerful ordnance than $12\frac{1}{2}$-ton guns are used. With reference to this point, in the naval attack on Fort Sumter, there was only one case in which three shots hit near the same place; and that structure, which underwent considerable pounding, consisted of only 5 ft. of brick-work round the guns. I think that Fort Sumter, bearing in mind that some 15-ton guns were used against it, underwent a much greater trial than our casemated structures would, if 12-ton guns were used against them. Here is a diagram* shewing our construction in reference to that which the Americans are now adopting at New York, Portland, and elsewhere, upon their coast. That block (pointing to the diagram) is the American construction. The construction adopted in this country is shown here; upon this the chain-dotted lines shew the English construction compared with the American construction. The plan adopted in this country has been to cut away all the weak part of the masonry and to introduce thick iron in its place, and to increase very much the mass of the pier by adding to its thickness in front and to a certain extent in rear. It is curious to observe that after the firing upon our pier at Shoeburyness the other day, the granite was still thicker than that which the Americans start with. The American construction is shewn in red, ours in black; and upon the diagram is indicated the state of the pier at Shoeburyness as it was after the firing. I grant that the diagram does not quite represent the whole effect; at the same time I do not think Colonel Collinson's representation of the effect produced upon the structure was quite correct†. He said the pier was cracked right through. No doubt

* See Plate III.

† Lieut. Col. Collinson had alluded to this experiment while reading his paper.—Ed.

the brick-work in the rear was cracked, but that was, in great measure, owing to the comparative lightness of the material at the back, which is of brick-work, and which the blow of the shot caused to be sent back from the heavier material. We have not, however, used brick-work in rear of the piers of most of our casemated sea forts; generally the piers are constructed of stone throughout. The experiment, no doubt, has been of great value in showing us that it is desirable to cramp all the stones of the piers together, so as to make them one mass. But, even supposing that the pier *can* be knocked down, it does not follow that the work would not answer its purpose. Many have got into a habit of late of looking after invulnerability, they are not satisfied if they see a crack in a structure after it has been fired at; but I think, when we consider the circumstances under which the work would be used, it will not be thought advisable to run away with the idea that casemated sea batteries should be invariably constructed wholly of iron. There may be cases where it is desirable, but I do not think the practice is one for general application. The amount of money that can be obtained, either in this or indeed in any country, for fortificational purposes, is limited, and we must consider what is on the whole the best mode of applying the funds at our disposal, not what will give absolute invulnerability in a particular work. As regards the application of iron to land forts, I believe it will be found sufficient to adapt it to works during a time of war, or at a period of expected attack. What appears chiefly to be wanted are iron shields at the embrasures to prevent the guns in the works being easily silenced, and, perhaps, in certain cases, we might put guns into cupolas upon turntables. The chief objection to cupolas is their expense. As regards the protection of caponiers it seems to me that it is not necessary, for if the caponiers are well sunk in the ditch they cannot be hit by the enemy's batteries until he comes to the edge of the ditch, and then, whether plated with iron or not, they would soon become untenable. I may mention that I believe the expense of 9-in. plates as also that of large plates, is very much overrated. When the machinery is once made, I believe it will be found that within certain limits the expense of plates per ton will not greatly exceed that of iron of narrower dimensions which could be used in the construction of forts, and that within certain limits thick plates will not cost much more in proportion than thinner plates.

CAPT. INGLIS: An ironmaster will tell you that the price varies exactly with the price of the roll that he has to make.

LIEUT. COL. JERVOIS: I asked the Secretary of one of the three great iron rolling firms, the other day, and he told me there was no great difference in the price per ton between the 6-inch plate and the 9-in. plate, and but little difference between that of laminated plates, when put together, and 6-in. plates.

CAPT. INGLIS: I do not see how they will do it.

LIEUT. COL. JERVOIS: There is a difference, no doubt, but not so great as is generally supposed.

CAPTAIN NEWSOME: There is one point Colonel Collinson has mentioned in his paper on which I should like to make a few remarks, that is to say, respecting the form of iron in the casemates. I think it is perfectly possible that there may be some instances in which it is very desirable that the guns should be perfectly invulnerable, such as at the entrance to an harbour or some point which it is desirable to protect. It seems to me that all casemates which have been at present designed or brought forward are on the vertical or plane principle. I think the true form to reduce anything to is the minimum; the minimum we could reduce a casemate to would be a sphere, and the minimum we could reduce an embrasure to would be naturally a circle; if we were in exposed situations we should reduce the casemates to spheres, open in rear, to allow ventilation, and separate them. I consider it is most important that they should be separated, as then, instead of drawing on them a concentrated fire, it would be a divergent one. Three or four guns could be mounted in separate casemates of that form composed internally of cellular iron, and externally of plates 3 or 4 inches in thickness, rolled, and of a spherical form, for I believe that is a form of casemate certainly preferable to any I have seen designed up to the present time. The guns in them could be worked by hydraulic presses. When we go to experiments we should employ all the means in our power, and not content ourselves with the existing means. I think iron backing is most important and valuable, and that we are altogether wrong in using backings of wood or stone for iron armour, as nothing but iron will take the shock of iron. One point that was brought forward to night, and which is very true, is, that the more complete you make a casemate, and the more you get the shock on the whole, the better; and no form is so calculated to take the shock as the spherical form. I simply wish to suggest that this in exposed situations should be the form adopted for the casemate—cellular inside of iron, and coated externally with as heavy armour as is found necessary.

THE CHAIRMAN: Like a series of cupolas.

CAPT. NEWSOME: I do not propose them to revolve at all, I propose them simply with everything reduced to a minimum.

THE CHAIRMAN: They might revolve, might they not?

CAPT. NEWSOME: I do not see the object of their revolving. They would be more expensive to make. The great difficulty in working the cupola is to make it revolve. I should propose these to be fixed, and the gun to move through a very large amount of training, by means, as I say, of hydraulic presses. I think that is the simplest way of moving heavy guns.

COLONEL OWEN: I have very little to say upon the subject. I have no experience of the effect of iron upon casemates. I have scarcely ever had an opportunity of seeing, (in fact I have not had the opportunity of seeing), a gun fired at an iron plate. I have read the account of the experiments at Shoeburyness, and I have seen the drawings that Colonel Jervois has been good enough to show us this evening; and I must say, as far as I can form an opinion on the subject, I think the result is exceedingly satisfactory. It has given me greater confidence in the efficiency of the works constructed at Plymouth and elsewhere, than I had before. Here and there, in details, they may be improved, and we are improving them daily.

LIEUT. COL. JERVOIS: It may be interesting to mention one or two different kinds of iron forts that have been proposed. One proposal is for a fort having guns on turn tables—(Coles' cupolas)—all round. I do not believe, that if that plan is gone into it will be found a desirable one to adopt, partly because of the expense, and also because, except in the case of small towers from which a command can be obtained from each gun, all round or nearly all round, the advantage for which a cupola is designed is not acquired. Another plan, an admirable one, has been proposed by Capt. Inglis, for covering the gun only by a small and nearly circular shield. This plan, however, necessitates the expense of a long iron shield between each gun; the entire cost notwithstanding for each gun on this plan would be less than that of a cupola, and 120° lateral range is obtained from each gun. This is as great a lateral range as can be obtained from cupolas, when placed in a row upon the parapet of a fort. Lately we have considered the turn-table principle again and again, and Mr. Guthrie, a very clever draughtsman now employed in the War Office, has prepared detailed drawings of a plan for using turn-tables, which I think possesses great merit. This plan is to have in each casemate a turn-table with a segmental iron shield in front; the turn-table gives the means of firing the gun through two embrasures. On the turn-table are racers, which, as in ordinary cases, give in each embrasure the means of obtaining a lateral range of about 70 degrees. The fire from each embrasure crosses at about 50 yards in front of the work; and thus about 150° lateral range can be obtained from each gun. In a casemated fort of a circular plan, and with 22 or 23 casemates, all the guns in any semi-circle, except two, will fire in one direction. There is one objection to the plan, viz., that in firing at an extreme lateral range, the effect of the blast from the gun through the nearest embrasure would produce a disagreeable effect upon the gunners in the adjoining casemate. One or two contrivances have been worked out with a view of meeting this objection.

LIEUT. COLONEL COLLINSON: I am sorry Colonel Jervois thinks I did not make quite a fair and reasonable statement of the effect of the shot upon the casemate, because it was my wish to do so.

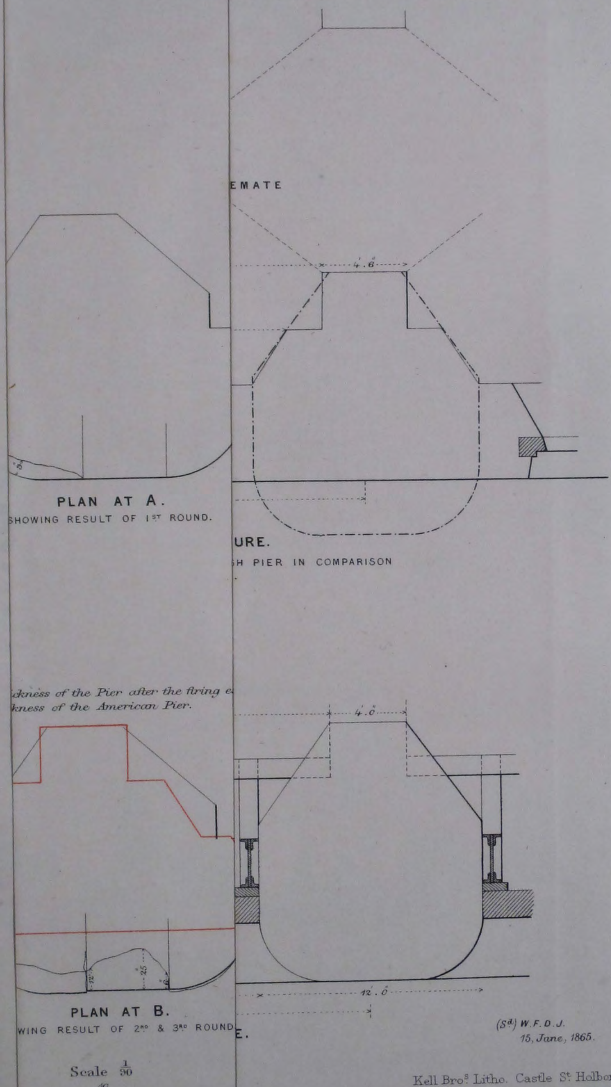
LIEUT. COLONEL JERVOIS: Only about the crack.

LIEUT. COLONEL COLLINSON: I expected to see greater effect upon it, but still having thoroughly examined it, I came to the conclusions I have mentioned, not that it might be affected by three shots, but that there was a danger that a few shots from guns of that nature might, by cracking a pier of the description, shape, and size in question, render the guns adjacent to it ineffective. It is with that view that I wish all our young engineers to consider this question of iron. I think everything bears me out in saying it is a question of efficiency and economy. Take iron as a material, compare it with any other material you have got, and see whether it will produce you a more effective fort or casemate without much additional cost. I do not say it would be exactly the same cost, but I do think, if you use a proper arrangement of iron, it will not be a much greater cost. The estimates I have made, and that will be printed in this paper, have been made from prices supplied to me from rates that have been paid at Shoeburyness, and they are made by men under me, whose business it is to make estimates, and I believe they are as fair as can be made for the purpose. I think they do fairly show that there is a possibility of producing an iron casemate that will be not much more expensive than the masonry casemates of the size and form which I think are necessary, and yet will be very much more effective.

THE CHAIRMAN: I am sure we are very much obliged to Lieutenant Colonel Collinson for the very interesting discussion to which he has led the way. I think he has shown us that we must depend upon experience more than theory at present in deciding what is to be the best form of application of iron; but still we must not discourage ingenious men from attempting to produce new systems. I hope that at our next session we shall find some new ideas started upon this subject.

Pl. XI.

] SYSTEMS OF CONSTRUCTION.



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PAPER VI.

NOTES ON THE BHOOTAN STOCKADES OF MYNAGOREE AND DHOMHONIE,

CAPTURED BY THE FORCE UNDER COMMAND OF MAJOR GOUGH, V.C.,

NOVEMBER, 1864.

By LIEUT. W. H. COLLINS, COMMANDING SEBUNDY SAPPERS.

The country of Bhootan lies to the north-east of Bengal. It may be considered as divided into two portions: one very mountainous—being the prolongation of the Himalayan Range; and the other, up to the foot of the hills, almost completely level, called the Bhootan Dooars. It was for the occupation of these Dooars that a force, consisting of four columns, assembled in November last, at four points almost on the boundary line of the country. Immediately in front of the left column, whose head-quarters was the frontier station Julpigoree, lay several Bhootea forts, among others Dalimkote. It was for this column to gain possession of these points, and then move eastward and join the column to its right. To the immediate right and right front of Julpigoree were known to be several Bhootea stockades. It was considered advisable to detach a small portion from Brigadier General Dunsford's column to gain possession of these stockades, and having done so, effect a junction with the main body before the latter should reach the first range of hills. For this purpose a small force under command of Major Gough, V.C., consisting of cavalry, artillery, and infantry, and sappers (under myself), with European officers, crossed the Tiesta on 29th November, 1864. The following notes have reference only to this force, and the stockades of Mynagoree and Dhomhonie captured by it. The river Tiesta forms the boundary between the British territory and Bhootan. It is a broad rapid river with a soft sandy bottom. It varies in depth with the melting of the snow on the Himalayas and periodic rains. At this time it was falling rapidly, but still at all places too deep to ford, even for elephants. The point where it was decided to cross was about four miles below the cantonments of Julpigoree, a point which the natives had been in the habit of using for a ferry. The far bank was soft deep sand, left bare by the retreating water; that, on our side, firm clay. Rafts constructed of native boats had been previously prepared by Lieutenant Armstrong, R.I.E., and myself, with a view to the passage of troops and stores. Native boats, which abounded on the river, had been seized by the civil authorities and handed over to us. These boats were of two descriptions, made either from the solid tree, the inside of which had been burnt and scooped out, or of planks neatly fastened together by iron clamps. The latter were flat bottomed; stern and bow were both alike, sloping gracefully upwards. They were considered by us much better than the others, if time and means for caulking them could be provided. Their cross section was wedge shaped, which rendered them infinitely preferable for rafts to the others whose section was almost circular, as each additional inch of immersion gave greatly increased buoyancy. Great difficulty was found in making the natives give up their good boats; these were made away with by their owners, or the natives employed to collect them took a bribe, and allowed them to escape. This, coupled with the fact that if we undertook to caulk the boats the very worst would be handed over to us, that the owners might have them repaired free of expense, obliged us to use both kinds. The hollowed out boats being not nearly so liable to leaks, went far to counterbalance the advantages of shape in the others. The idea of the raft was taken from the native ferry boat, used to carry stores. Baulks of bamboo were laid across four of the hollowed out boats, or three of the others, and on the top of these, platforms made of split bamboo were laid and lashed. As everything except the *kookeries* (or knives) which the Sappers carried with them had to be found or made, we were fortunate in being in the country of bamboos, and in having very handy workmen. During the preparation of these rafts I found it expedient to divide my detachment of Sappers into parties, one of which made rope out of the fibre of a sort of reed, another cut bamboos, another repaired boats, and another made platforms. We abandoned the idea of a bridge at this point of the river. We preferred to use the ghât, or bank, already in use, and to cross a narrow place by rafts, rather than a wider and perhaps less convenient place by a bridge. I thought time and labour might be saved by swinging across by a rope fastened to a pole sunk in the stream; but on trial it was found much better to allow the native boatmen to pole the rafts across, making their own arrangements. One is apt to consider that arrangements convenient at home can be substituted with advantage for native means of doing things; but this is not so. Natives seem to prefer to do as they have always done, and time is lost and confusion created by altering their ways. As it was decided that all stores proceeding to Kooch Behar, the head-quarters of our right hand column, should pass at the same point of the river, it was necessary to make a more convenient ghât. The bank had to be cut down to a convenient slope, and its toe, from which the water was daily receding, to be strengthened. This I effected by constructing fascines of bamboo, twenty-five feet long, and picketing them on the water's edge; when the water had retreated, another row was secured below the one already fixed.

On the morning of 29th November, our force left Julpigoree at 5 A.M., and crossed on the rafts without accident. The elephants which carried the artillery and stores having been unloaded swam across; the mortars, &c., were carried over on the rafts, and the elephants were reloaded on the other side; about four miles from the river we encamped. The heat was so great even in this month that during the day it was almost unbearable. My detachment of Sappers had not been provided with a tent, and it became necessary to erect some sort of shed to protect them from the great heat by day, and from the heavy dew at night. In half an hour they had built themselves sufficient shelter.

Efforts were made to obtain all possible information with reference to the stockade which it was our intention to take on the following day, but without success. So bad was our information upon all points up to the present time that we were ignorant of the nature of the stockade or the number of its garrison; although, as it turned out, no resistance was offered, all necessary precautions were taken, and it was not till we reached the stockade that we learned that our preparations were not required. I was directed to prepare for breaching by powder, and for an assault by escalade, should this be deemed necessary. My only guide as to the nature of the wall or revetment to be breached was what could be seen of a stockade which it was also intended to take, and which was visible from the river some miles above Julpigoree. General Dunsford had issued orders against any effort at reconnoissance, lest intrusion on the Bhootea land, before war was declared, should be deemed by them an offensive demonstration on our part. I had therefore to content myself with a very imperfect view through a glass. It was apparently a wall of bamboos, the thickness of which could not be ascertained. There seemed to be no ditch in front. As well as I could see there appeared to be towers at each corner for flank defence.

The only materials at my disposal were a stick of port-fire given me by the Artillery, and a few strands of quick match. With these, and some bags I had made before leaving Julpigoree, I prepared a powder-bag and fuse. As these answered with perfect success, both here and afterwards at the assault and capture of Dalimkote, their construction may be interesting, and, under similar circumstances, can be repeated. 60 lbs. of powder were placed in a linen bag, the fuze hereinafter described was introduced, and the mouth of the bag gathered round it, and tied to it. This bag was placed inside another, and the mouth similarly closed. Some mombjama, or waxed cloth, which I found round the powder barrel I had brought with me, was next wrapped round the bag, and two coarse pieces of native cord matting separately bound round it. As it was my intention to carry the powder with me, ropes were secured to the bag, as shewn in sketch, and a light piece of bamboo cut for a pole. (See Fig. 5.)

The fuze was prepared as follows:—A small piece of linen hose, about a foot long, was prepared and left open at both ends. A piece of port-fire was cut about 2 in. long; the composition was scraped out of one end, so as to leave a little less than one inch remaining. Into the hollow part were introduced a few strands of quick match, with a few particles of loosened composition, and fastened in with paper. (Fig. 1.) Round the composition end of the case was tied one end of the empty hose. This was turned upside down and filled with powder, and a knot put on the end. (Fig. 2.) A piece of bamboo, just large enough to admit the port fire tube, was cut: it was made a little shorter than the fuze: it was split, laid round the fuze, and firmly lashed. The object of this was to prevent the possibility of fire passing at once from the quick match, or lighted end, to the hose. (Fig. 3.) To prevent the quick match from being knocked out, another piece of bamboo was put outside, projecting sufficiently to allow the quick match to be coiled within it. Over the whole was placed a cup of bamboo. (Fig. 4.)

To provide for an assault by escalade, ladders were made of bamboo. It appeared advisable to make them in double widths, as by this means one long piece was dispensed with, and breadth equal to two ladders afforded, natives being able to swarm up in numbers without inconvenience. Several raw hides were cut up, which gave stronger lashings than could have been made of the sun or hemp found in the country. These ladders had unwisely been made at Julpigoree before starting; as it was impossible to find stems of bamboo of the size required already cut and seasoned, they were cut and used while green. The consequence was, they had to be made over again at Bykalil, our first encampment, as the lashings were no longer of any use. It is advisable to construct nothing of green bamboos in which pieces are joined together, as they shrink greatly when drying. The ladders were 23 feet long and 4 feet wide.

On the morning of the 29th we moved forward at 5 A.M. There had been a tremendous dew-fall during the night, and the cold was intense. With great difficulty we packed four ladders on the elephant: the mahout was stupid or drunk, and the elephant, annoyed at the ladders projecting beyond his head, ran about, creating great confusion. When we thought we had secured the ladders firmly, he wheeled round and loosened them. The powder was carried in the ranks. On the march a native informed us that the Bhooteas had gathered in strength to resist us. On reaching the Mynagoree it appeared that, alarmed at our numbers, and having a great dread of cavalry, the enemy had abandoned the place. The stockade was found to be a rectangular work. The encircling wall was composed of bamboos, height from 25 feet to 30 feet, bound together by horizontal strips of bamboo, running inside and outside at vertical distances of 6 feet. At intervals these strips were lashed together through the wall: the whole sheeting was thus made firm and compact. The thickness of the wall was in some places 20 inches, in others only 9 inches. The bamboos were sunk about 2 feet in the ground; average diameter at the bottom, $3\frac{1}{2}$ inches, slightly less towards the top. Two sides were provided with sufficient flank defence; the other two were not so protected. Inside, at a height of 20 feet, a gallery ran round two sides of the quadrangle; it was 5 feet wide, supported on upright bamboos. From this a good fire could have been directed through loopholes in the wall, and through the irregular top. Almost in the centre of the work was a square building, raised on poles to the height of the gallery, communicating with the ground by a narrow staircase. There was also a stair, constructed out of a single tree, in one corner leading to the gallery. On one side the wall was loopholed at the height of a foot from the ground, by hollow pieces of bamboo fixed through it: the ground immediately below these loopholes being excavated slightly to allow of their being used. These loopholes had of course no splay, but their great number made up for this defect, as they pointed to all parts of the ground in front. It was at once apparent that no assault by escalade could have been attempted without great loss of life and perhaps failure. As it was, the scaling ladders were about 5 feet too short. Under any circumstances the ragged edge of the wall would have rendered any attempt to cross extremely difficult. The uncertainty also of what might be on the other side, put this mode of attack out of the question. The horizontal bamboos which ran at intervals along the side of the work in a measure supplied the necessity of ladders, giving a sufficient footing for active men to climb up. Afterwards, such an attempt was made, and the top crossed, though to have done so under fire would have been rash. The stockade appeared to me to be of a very formidable character, and capable of maintaining a strong defence. There was one large entrance in the centre of the projecting tower; curiously enough this door was about the only place not covered by flank fire, and a projecting roof screened it from the fire overhead.

As this stockade was perhaps a type of others which it would be necessary to take when opposed, it seemed to me most desirable that the nature of the revetment and the resistance it would offer to breaching by powder should be tested. By permission of Major Gough I was allowed to experiment with this view, taking care that none of the buildings inside, which were roofed with thatch, should catch fire. Had it been necessary to enter the work while opposed, I should have chosen the entrance door as the most favourable spot for a breach. As it was, I selected a place where the danger from fire appeared least, and where the bamboos were most firmly fixed together, viz., at a point in the wall opposite to the entrance. The bag of powder was laid at the foot of the revetment, and two large bags of earth each weighing about 2 mds., or 160 lbs., were placed over it. (Fig. 6). The fuze being lighted, 58 seconds elapsed before the explosion, giving more than ample time to retire to a safe distance. On the clearing away of the smoke, I was greatly surprised to see almost no effect produced. With difficulty two men made their way into the work using their knives. On closer inspection it appeared that a breach had in reality been formed about 4 feet high by 5 feet wide, but that the bamboos having merely been shortened in length had fallen perpendicularly downwards like a portcullis (Fig. 7). One method appeared possible, by which a complete opening could be produced, viz., by directing men to climb the wall and cut the horizontal rods, which held the bamboos in their places, while they had allowed them to descend. These being cut, the whole of the broken and splintered uprights would have fallen forward. To do this would have taken time, and under fire would have been hazardous. The experience gained by this experiment, on account of its only partial success, was even more valuable than I had anticipated. Double the quantity of powder used would not have made an efficient breach. It appears to me that no kind of revetment can be better adapted for the purposes of stockading than one formed in this manner. The tough elastic fibre of the bamboo gives a strength to a revetment of this nature that ordinary palisading could never have. Charges, to be effective, must be much larger and differently arranged than in ordinary cases. To have attempted to breach this wall with round shot would have been useless, as the fibre would have closed over each hole made, and shells would have been little better. The portion of a bamboo actually struck would be the only part cut, and no one rod would have fallen unless completely severed. The dry bamboo is also extremely difficult to burn, so that but one method of effecting a breach in a work of this nature remains, namely by powder. To do so effectively, at least two charges of 70 or 80 lbs. should be exploded. They ought to be placed at a distance apart of about 5 feet. To explode them above the ground at the height of a few feet would be more effective than on the ground; but to put them in this position and load them on the outside would be difficult. No nail could be driven into the bamboos, and the horizontal strips might not run at a convenient height, to be used as a means of attaching them. The following plan was arranged by me, in case it seemed desirable to suspend the bag at a height. (Fig. 8). Two long bamboos, with ropes at one end, were made fast to the bags of powder and earth. When the rods were laid at an angle against the wall the bags lay in their proper position against it. This arrangement would also have the advantage that no time would be lost in firing the charge, which could not be the case if nails had to be driven.

The garrison of Mynagoree had wisely fled, as sooner or later we should have taken the place, but the ingenuity of construction and obstinacy of defence possible would have almost tempted a spirited leader to make a stand. To have set fire to the buildings and dropped in shells would have been easy, but it is probable that had complete arrangements for defence been made, the roofs would have been taken from the houses. Afterwards, at Dalimkote, the surest intimation given of intended resistance was the taking down of all thatched roofs. On entering the stockade it appeared that the Bhooteas had smeared all posts and doors with pigs' blood and fat. The stench was something frightful. Whether they had done so to offend our prejudices, or that the fort presented only its usual appearance, we could not say. It would have been impossible to locate Europeans in it; fever or some disease would have certainly followed.

The Dhomhonie stockade, taken on 31st November, was perhaps more carefully built, but the walls were not so high as those of Mynagoree, nor were the internal arrangements so good.

On joining the main body of the force it appeared that during the absence of our party a bridge had been constructed over a branch of the Tiesta. Numbers of rafts already described were laid together, and the projecting edge of one was laid over the edge of the other, and the boats thus brought together firmly secured. The disadvantages of this construction were manifest; each raft was itself on an incline, and one boat of each considerably sunk in the water; a step was also produced in the roadway by the overlapping of the platforms, which was injurious to the wear of the bamboo flooring, both from the sudden fall of carts passing over, and the greater strain exerted on the roadway in pulling loads across. Another defect was the limiting the width of waterway, the outside boats of each raft being side by side with those of the raft next them. While the step on the roadway was injurious to its permanence, the overlapping of the platforms caused in the aggregate a great loss of good roadway and rendered more rafts necessary. The advantages of this construction were, simplicity, and the facility with which a bridge so made could be dismantled into rafts.

W. H. C.

Fig. 1.

PORTFIRE TUBE.

Fig. 2.

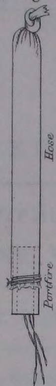


Fig. 3.

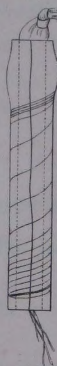
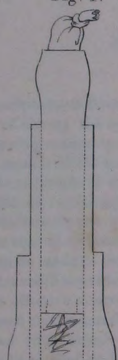
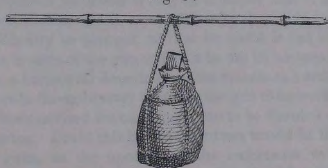


Fig. 4.



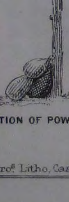
FUSE COMPLETED.

Fig. 5.



BAG AS CARRIED IN THE RANKS.

Fig. 6.



POSITION OF POWDER BAG.

Fig. 7.

APPEARANCE AFTER EXPLOSION.

Fig. 8.

PROPOSED PLAN OF FIXING BAG AT AN ELEVATION.

Kell, Bros. Litho, Castle St. Holborn.

PAPER VII.

BALANCE MUSKET-PROOF SHUTTERS FOR EMBRASURES, WINDOWS, &c.

By CAPT. E. F. DU CANE, R.E.

The advantages claimed for this embrasure shutter are, that besides the ordinary object of closing the embrasure, when the gun is not being fired, it also reduces the opening necessary to enable the gun to be fired to little more than the area of the muzzle of the gun; and that its parts are so balanced that hardly any effort is necessary to work it, whatever thickness it may be made, so that it may be made strong enough to resist missiles much more powerful than rifle balls.

An embrasure can without difficulty be planned so that its *width* is but little greater than the diameter of the muzzle of the gun which is to use it, because the gun can be made to traverse (in a horizontal direction) on the muzzle as a centre. No extra *width* is wanted therefore in the embrasure to enable the gun to be worked. But no effective means has yet been devised for enabling a gun to be elevated and depressed on the muzzle as a centre. Could this be done, shutters would be little required with breech-loading guns, as the opening of the embrasure would always be blocked up by the gun and little room left for the entry of musket balls.

As matters now are, the gun, moving on the trunnions as a centre, in elevating or depressing its muzzle, requires certain play in a vertical direction, so that the embrasure for an 8-in. gun, which is 18 inches in diameter at the muzzle, requires to be made 2 ft. 11 in. high at the neck, to allow 10° elevation, and a depression of 1 in 6, while the width of the embrasure at the neck need not exceed 2 feet.

It is clear that a shutter working on hinges at the side must, when open, expose the whole area of the embrasure; and the construction of the shutters now under consideration meets the disadvantage of having an opening considerably larger than that occupied by the gun, as it is easily seen that the shutter need not be opened to any greater extent than will just admit the muzzle, so as to enable the gun to fire.

The loops on the rope on which the shutters hang, are fixed in such positions that the shutters, when open, will uncover not more space than is necessary to enable the gun,

1. To fire point blank.
2. To fire point blank and with depression.
3. To fire point blank and with elevation and depression.

The upper part of the shutter balancing the lower part, enables them to be moved with very little exertion; and without the addition of strength and size of parts necessary when the object is effected by counter-weights, which, of course, double the weight to be moved and carried, besides some other disadvantages; and this would be a serious consideration if shutters should be adopted able to resist heavier missiles than musket balls.

Shutters on this principle have been designed for fixing to the windows of barracks intended to act as keeps in a post. In this case it is more convenient to make a shutter in four leaves instead of in two, in order that when opened it may lay conveniently in the space available for it.

It must be observed that none of the important working parts of this shutter are at all exposed, as is the case with those shutters which work on hinges.

The following report made by the Ordnance Select Committee on this shutter, which was tried together with one by Mr. Millard, is published by permission.

36. *Musket-proof Shutters for Embrasures, proposed by Capt. Du Cane, R.E. Collapsing Mantlets, proposed by Mr. Millard.*

Minute 11,131. 24—2—64.

REPORT No. 3,201. (4—3—64).

The Committee proceeded on the 6th February to examine the condition of the iron mantlets on Capt. Du Cane's and Mr. Millard's principles, which had been fitted to two gun casemates at the Drop Redoubt, Dover, and had been exposed to very heavy musketry fire for the purpose of testing their relative merits, facility of working, stability, &c.

The joint report of the Commanding Officers, Royal Artillery and Royal Engineers, Dover district, enters so fully into the details of the recent trial, that the Committee think it unnecessary to repeat them at any length.

Judging from the opinion expressed in that report on the relative merits of the two mantlets, combined with their own personal observations, the Committee think it conclusive that both Capt. Du Cane's and Mr. Millard's mantlets are so much superior to the present regulation mantlet, that that pattern should be abandoned in all future manufacture.

As regards the service of guns in casemates, Mr. Millard's mantlet has the advantage of being self-acting, whereas Capt. Du Cane's mantlet requires to be opened and closed by hand, although the operation requires but very slight exertion on account of the counterpoise construction of the shutters. When loading, it is necessary to open Capt. Du Cane's mantlet about 2 inches, to admit of the protrusion of the sponge and rammer.

This inconvenience would be obviated by the employment in flank defences of breech-loading guns, or of light wrought iron smooth-bored guns, which would give sufficient recoil to clear the embrasure when loading, and in other respects be much more suitable than the heavy cast-iron guns usually mounted in such localities. When the gun is run out, the opening necessarily left by the gun is, with Captain Du Cane's mantlet, 1 ft. 7 in. in height × 2 ft. in width $= 3\frac{1}{6}$ square feet; with Mr. Millard's mantlet, 2 ft. 6 in. in height × 1 ft. 4 in.

in width $= 3\frac{1}{3}$ square feet;* but as the latter is self-acting and collapsing, the embrasure becomes more readily closed, as the shutters resting on the neck of the gun close instantly as the gun recoils.

Captain Du Cane's mantlet was made of wrought iron $\frac{3}{16}$ inch thick; that of Mr. Millard of $\frac{4}{16}$ inch iron, and neither of them were perforated by the file or volley firing. The former was proof against the very severe trial to which it was subjected, and did not admit a single bullet, but it was considerably bulged, and so much injury was done to the wooden groove in which the shutters slide, that the mantlet set fast, and could not be worked even with the aid of a handspike.

Mr. Millard's was not constructed originally for the embrasure to which it was fitted. A space of about 2 inches had been left between the top of the mantlet and the head of the embrasure, and consequently any bullets striking in that direction were deflected into the gun-room.

The Committee are of opinion that the defects which have presented themselves may be readily overcome by the exercise of a little ingenuity on the part of the proposers, and by adopting in new constructions such improvements in the mode of fitment as the results of the late trial appear to suggest.

They think that Captain Du Cane's mantlet should be made of slightly increased thickness, say $\frac{4}{16}$ of an inch, and that the groove in which the half-shutters slide should be lined with iron so as to keep the groove free from the lodgment of splinters of wood.

There is little difficulty with Mr. Millard's mantlet, if constructed to fit the embrasure.

The small space which is left between the upper edge and the head of the embrasure for the purpose of allowing the shutters to be lifted so as to clear away any debris that may accumulate on the sole of the embrasure, may be closed by shutting the sides against an iron rabbet let into the stone or brickwork.

The Committee consider that both these mantlets have special advantages; that of Captain Du Cane's pattern appears to be superior to that of Mr. Millard's, when required to fit a window or casement in inhabited works, or for iron embrasures, should such come into use; but it is weaker in proportion to the width of the opening; and for wide necked embrasures, or where casemates are uninhabited, they think that the latter will often be found the more advantageous of the two.

Millard's also can be more readily applied to embrasures in masonry parapets of the usual height not casemated.

The Committee do not think it necessary to make any further experiments, but recommend that the proposers be called upon to furnish specifications embodying such modifications as they may consider necessary.

There will then be two patterns of mantlets, both possessing certain advantages over the only pattern which appears to be now recognized, and the Committee are of opinion that it should be left to the discretion of the constructing Engineer to adopt that pattern which he considers best suited for the particular nature of the opening to be closed.

* There must be some error in these figures.

SPECIFICATION OF CAPT. E. F. DU CANE'S BALANCE MUSKET-PROOF SHUTTERS FOR EMBRASURES, WINDOWS, &c.

Shutters generally.

The shutters to be composed either of homogeneous, rolled, or boiler-plate iron, of such strength and thickness as will resist musket or rifle balls, and which must be ascertained by actual test before fixing. To prevent buckling, and to insure the free action of the shutters in their frames, angle-iron 1 in. × 1 in., and $\frac{1}{4}$-in. thick, is to be closely riveted all round each shutter.

The shutters to consist of two leaves of equal weight attached to each other by a line passing over a pulley and balancing each other, one rising, the other falling; the line to have loops on it so arranged that the opening of the shutter can be graduated from 1 ft. 9 in. to the full size of the embrasure. A wrought iron handle to be riveted to the lower half to assist in raising or lowering; and two curved hooks or catches to be riveted to both lower and top shutter to take the ends of the lines.

The frames.

To consist of double-angle iron, 1 inch on one face, $\frac{3}{4}$ inch on the other, $\frac{1}{4}$ inch thick, and with a rebate $\frac{1}{2}$ inch deep, riveted (on each jamb) to a flat bar $2\frac{1}{2}$ in. × $\frac{1}{4}$ in., passing round the bottom and sides of the opening, and secured to the inside face of the work by lewis-bolts and nuts, or by screws driven into lead plugs. The head of the frame to be formed of angle-iron 2 in. × $1\frac{3}{4}$ in., and $\frac{1}{4}$ in. thick, and similarly secured to the wall, and the ends rounded off over the top of the side slides.

Pulleys.

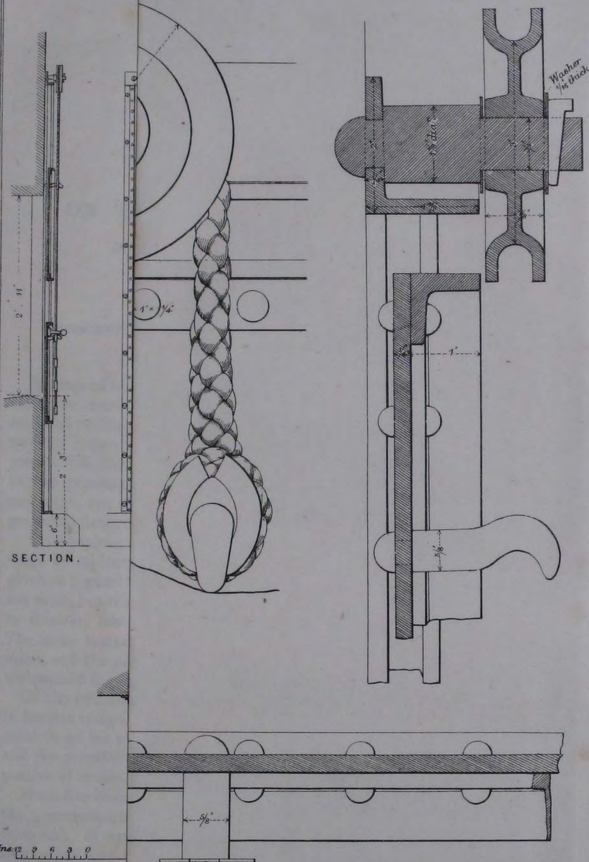
To be of cast-iron or gun-metal, 4 inches diameter, and $\frac{7}{8}$ inch on face, bored out, grooved, and turned, to work on a $\frac{3}{4}$-inch axle, which latter is to be shouldered full size of the boss of the pulley, and riveted to the angle-iron forming the head of the frame, projecting sufficiently forward to clear the angle-iron of shutters, with the necessary washers, keys, and slots to secure the pulleys.

The lines.

To be either hemp, copper wire, or riveted chain, of sufficient strength to sustain *four to six times* the weight of the shutters, having suitable "thimbles" or rings, attached by splicing to each end, to admit of taking off the catches for adjusting to the required openings as before referred to.

The whole of the iron-work to be painted four coats in oil and lead, the first two to be mixed with red lead.

E. F. DU C.



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6 7 8 9 10 11 12 *Inches*

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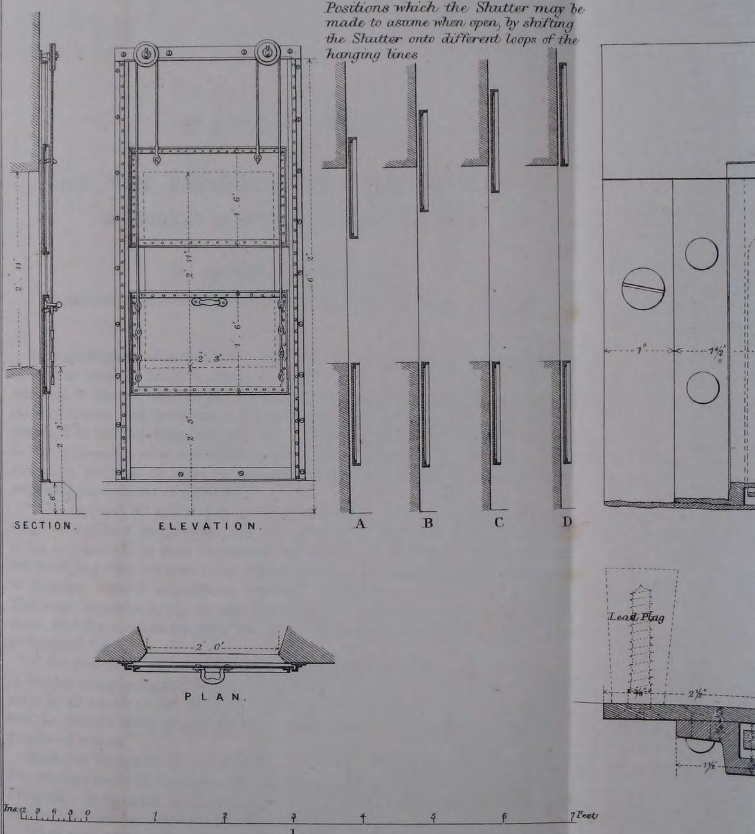
Kell Bros Litho; Castle St. Holborn.

BALANCED MUSKET - PROOF



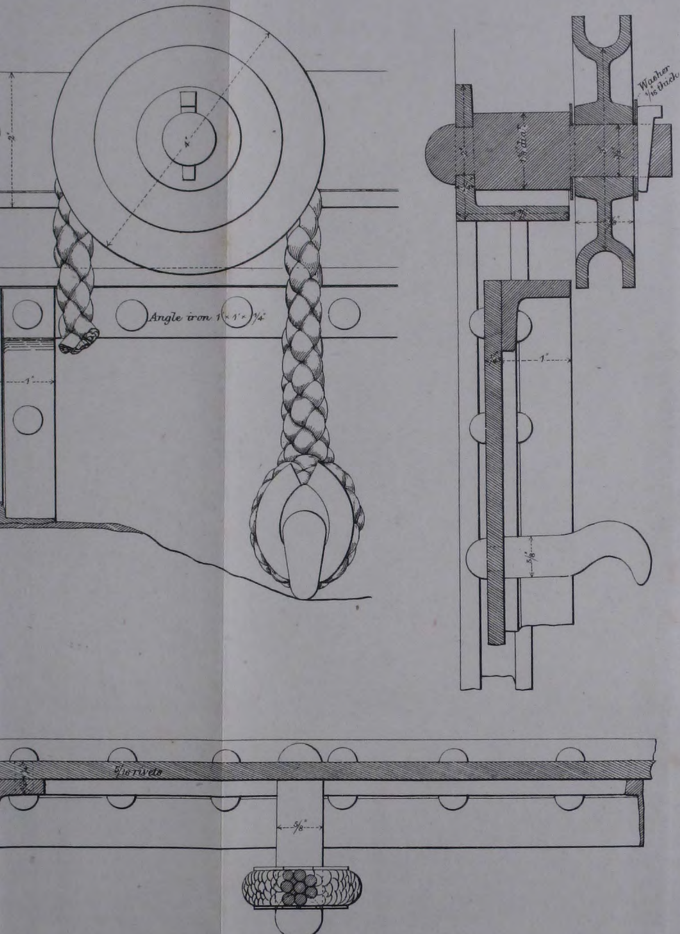
Note. *A narrow opening may be left between the Shutters to serve as a horizontal loop hole. When the full opening of the Embrazure or Window is not required either on account of the size of the Gun or of the Angle at which it is to be fired, the opening may be materially diminished by shifting the different loops of the hanging lines, onto the hooks of the Lower Shutter. Thus position A allows an eight inch Gun or Howitzer to fire with 10° depression only*

B in any direction between point blank and 10° depression

C in any direction between 5° of elevation & 10° depression

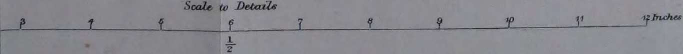
D in any direction between 10° of elevation & 10° depression

F SHUTTERS.



DETAILS ½ FULL SIZE.

Scale to Details



Kell Bro^s Litho; Castle S^t Holborn.

PAPER VIII.

ON THE REPRESENTATION OF GROUND,

ESPECIALLY IN MILITARY RECONNOISSANCE.

By CAPTAIN WEBBER, R.E.,

Assistant Instructor in Topography, Royal Military Academy.

Strategical maps of most of the countries of Europe are now to be obtained. Reference need be made to them no further than to state, that, they are as essential to the movements and combinations of an army on a large scale, as maps of routes and positions to the development of tactical manœuvres. It is premised in the following remarks that a general map of the country is always in the possession of a commander before he commences the operations of a campaign, and that it must be the basis of all the arrangements of the topographical department of an army.

"The aspirant for military fame can never attain his object without a knowledge of military geography, and the greatest praise that in France can be given to a general, is, that 'il connaît bien la carte.' Alone this knowledge will not avail, but that without it the otherwise ablest commander would be exposed to disaster, history abundantly proves." Thus writes Colonel J. Jackson. The same remarks apply to the knowledge of tactical as well as strategical maps, and the commander who has learnt to make them will be best able to understand them.

Of the two kinds the tactical map is the most difficult to comprehend, for on it, besides recognising the natural features, the general must take into consideration in all his plans the command of the ground, the inclination of the slopes, and the practicability of movement across an open or enclosed country, irrespective of routes.

Much has been written on the influence of the introduction of rifled arms on the arrangements of the scientific departments of an army, the topographical excepted. It appears to the writer that the operations of no branch of the service has been more materially affected thereby.

When men could only injure one another at arm's-length distance, the importance of natural or artificial topographical features was very limited; but when the use of projectiles was introduced into warfare, the configuration of the ground, and the nature of the obstacles on it, became important considerations for the commander, who had to look to more than the bravery and numbers of his army.

As the velocity of the projectile increased, the more caution had to be used; and the comparative safety of manœuvres within range depended on the forethought of the commander.

But when in the beginning of the present century, the demand arising from these considerations had produced in the British army the means for the rapid construction of maps representing the features of ground on a large scale, the system, though simple enough, proved too elementary for more than a limited number of intelligent officers to carry out in practice; and the incalculable advantage arising from the combination of a large number of operators was lost. Admirable sketches were produced by the exertions of a few individuals, but the desired results were often forthcoming only when the necessity for them had ceased, and they had been thus robbed of half their value; but they will always exist as records for the instruction of the student, as monuments of the untiring energy of their compilers, and as a warning to us that we are very far indeed from that summit where we may "rest and be thankful."

Instances of failure arising from imperfect knowledge of ground have been very frequent in past times, and in future they will be multiplied, if the accuracy of the information supplied by a reconnoissance does not increase in proportion to the improvements in the range and precision of armaments. If, therefore, a more truthful expression of *relative altitudes* and *inclination of slopes* be attained, the improvement, though probably not commensurate, will certainly accord with the requirements arising from the use of rifled arms.

Influence of rifled arms on military topography.

General Jarry estimated the depth of an army in position at 1 mile, and the ground to be reconnoitred and mapped at a depth of 3 miles, founding his estimate on the known range of artillery. At the lowest calculation we ought now to increase that depth to 4 miles, and similarly the ground on each flank will be increased from 3 to 6 square miles; consequently the front of the army being 2, 3, or 4 miles, the surface to be delineated is increased from 12, 15, and 18, to 20, 24, and 28 square miles.

When the General instructed our staff officers in the mode of sketching which appeared to him the most practical and expeditious, he never calculated on the searching accuracy of rifled arms, both in the hands of infantry and artillery. He rightly considered that even comparative accuracy in an estimate of command and inclination of slopes must yield to rapidity of execution in the details.

But while science has daily added to the number and efficiency of means of offence and defence, it has done little to increase the rapidity of, or to insure a more mechanical process for, placing in the hands of a commander an accurate picture of the "accidents" of the ground, which are destined to influence his use of all the means at his disposal. It is on this that the writer proposes to offer a few suggestions, and he may safely assert that nothing will be here put forward of which he has not proved the feasibility.

Lieut. Colonel Scott's scale.

Lieut. Colonel Scott, in his valuable paper on the "Representation of Ground," in Vol. XII of this series, has clearly proved that the best system for representing slopes is by horizontal hachures based on contours, silencing the advocates of the vertical system, and has at the same time suggested the use of a scale of shade as likely to produce uniformity in results of the work of different draughtsmen.

Although agreeing in all that the paper contained in favour of the contour system, the writer for some time strongly opposed the use of a scale of shade, which involved an alteration in the *number* and *thickness* of the hachures, corresponding to the horizontal distance between the contours.

The objection to it appeared to be, that there would be little hope of training more than a very limited number of draughtsmen to distinguish between ten or more gradations of *thickness* of line, varying only by a very small fraction of an inch; and that no matter how few the changes in *numbers* of strokes, the draughtsman in the field would be delayed by having to recollect or mark them off from the scale, at each point of divergence of the contours.

As regards the scale proposed by Lieut. Colonel Scott, the writer found; that its arrangement did not meet all the requirements of Hill sketching in the field, owing to the assumption of the vertical unit of 5 feet, which, although equalling two 30-in. paces, did not bear sufficient relation to the average pace and height of eye to meet the requirements of beginners on large scales, so that the difference of level might be reckoned in paces; that the vertical distance in feet at which contours were shewn varied five times in the same scale with the angle of inclination, instead of being as much as possible at an uniform difference of level, and shewn at a horizontal distance proportional to the cotangent of the angle of inclination of the slope; and lastly, that there was a departure from the old scales of inches to a mile, which have proved so convenient in our ordnance as well as in our military surveys.

As no one could read the paper referred to without being impressed with the importance of the move towards which Lieut. Colonel Scott was leading, the writer was obliged to alter his opinion, formed against the use of a scale of shade when he tested its value as an assistant to those who, without it, never could have made anything like an accurate representation of a contoured model; and who, in consequence, though not adhering to an accurate thickness of touch, produced a wonderful uniformity in effect; these crutches (so to speak) enabling the lame to progress almost as well as on real legs, and not retarding the movement of the few who do not absolutely require them.

With a view to simplicity and to meeting the requirements of the beginner in the field, the writer suggests the use of the scale in Plate I. Taking as the basis of construction the average pace as equal to 32 inches, and height of eye equal to 64 inches, and meeting the advantages derived from the use of a scale of 33rds of an inch, then on a scale of

1	inch to	1 mile,	$\frac{1}{33}$ of an inch	equals	60	paces
2	„	„	„	„	30	„
3	„	„	„	„	20	„
4	„	„	„	„	15	„
5	„	„	„	„	12	„
6	„	„	„	„	10	„

and their multiples so far as convenient.

Again, assuming 60 inches to a mile as the scale on which contours would be shewn at a one-height difference of level, then at the slope of 45° the horizontal distance between them would be two paces (or thirty-thirds of an inch) apart; at every other angle the distance between them in thirty-thirds would be the cotangent multiplied by two; and half that distance when half contours were introduced to express the varying slopes at the lower angles of inclination. In the smaller scales, of which 60 is a multiple, the contours will be the same distance apart in plan, but their difference in level will vary inversely in the same proportion, thus:

Scale of inches to 1 mile.	Lower angles of inclination. Half contours shewn at	Higher angles of inclination. Whole contours shewn at
60	½ Height.	1 Height.
30	1 „	2 „
15	2 „	4 „
12	2½ „	5 „
10	3 „	6 „
6	5 „	10 „
4	7½ „	15 „
3	10 „	20 „
2	15 „	30 „
1	30 „	60 „

With these data, a surveyor, having fixed the horizontal distance between any two points in plan, can ascertain their difference of level in heights and paces by observing the angle of inclination between them, and dividing the distance accordingly by the division on the scale of shade representing one contour; the proportional difference being estimated for an intermediate angle.

Contouring. In a sketch, where he had laid down the main lines, he would ascertain the greatest number of contours in a sectional line by roughly levelling, or by taking the angle between the highest and lowest points, numbering them, and adhering to their level in sketching in the contours through the rest of the work. The number of sections to be taken in addition would entirely depend on the time available; but it is evident that they might be multiplied so as to allow of the contours being sketched in with great accuracy; and that even one such section, and the determination of the relative levels of the most important heights, would give an approximation which would be infinitely superior to imaginary contours, occupying more time and thought in the drawing, than the simple process here described.

An elaborate description of the process as carried out in an example would be extraneous. Any officer accustomed to sketch would at once be able to carry out the suggestions in all cases that might occur, and each step is so mechanical that any one could learn it in a short course of instruction.

The distance for half-contours, although only given at the lower angles, may be inserted if necessary at the steeper inclinations, wherever a sudden change of slope, or an eminence of less altitude than that laid down for a whole contour in the scale, has to be defined; the only precaution necessary being to number them as 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, &c.

Plate I. The scale of shade. The scale of shade of which an illustration is given, is assumed to be in the most convenient form; it is drawn as engraved on the edges of the flat side of a protractor, the space between being filled by the usual diagonal scale of inches. In the outer columns on each edge, the calculated distance between contours for each angle is divided; in the higher angles three contours are shewn for each, as an assistance in marking off a uniform slope, and to isolate the shaded portions; at 5°, 4°, 3°, and 2°, one contour is given. The middle columns are divided as the outer, with each space numbered, to remind the worker that it represents a whole or half-contour. The inner columns are divided and figured so as to shew which portion of the scale belongs to each angle. The table attached to the figure in Plate I gives the calculated dimensions, and the thickness of hachures in decimals of an inch.

Plate 2, Shading.* To use the scale of shade we must assume one or two examples of a piece of ground contoured with a greater or less approximation to accuracy. Two are given, one more sharply defined than the other, each comprising the whole of a spur of a hill to the watercourses bounding it. A beginner should adhere to the following steps in the process, which he will be able to dispense with by degrees, as his hand and eye become trained to the work.

Practice proves that the axis of each set of hachures should be a line perpendicular to the contours, generally continuous from watershed to watercourse; and nature points out the same direction for the flow of water. Therefore, "guiding lines" are introduced as shewn on the right side of each feature, Fig. 1, the rule for which is, that wherever they are, they are drawn, if possible, from watershed to watercourse, in a direction always perpendicular to the contours, where they cut them. These lines thus serve as guides to the general direction of the axis of each set of hachures, but are in no way intended to define the boundary of the ends of the touches; and it is not feared that any one who sees the effect that can be produced in truthful representations of smaller features by breaking the edge, will fall into such an error.

As time is always an object in the field, there is no doubt that each feature of ground should be completely shaded throughout before leaving it, instead of, as is commonly the habit, shading round a hill between one or more contours, and then returning to complete a lower level in the same manner. To do this, it will be only necessary to complete the feature as bounded by watercourses, contour it, and insert the guiding lines, in pencil, as illustrated in Fig. 1; concluding by applying the edge of the scale of shade to the watercourses, watershed, and "guiding lines," and marking off the touches that should be included between the contours, according to their distance apart, adjusting them to suit where the spaces do not quite agree, as shewn on half the features in Fig. 2. Shading should then be commenced on right slopes from watershed to watercourse, and *vice versa* on left slopes, without stopping at the contours: defining

* The writer is indebted to Capt. Hutchinson, R.A., Assist. Instructor in Military Topography at the Royal Military Academy, for the execution of this example.

right and left slopes towards a watercourse, by the same rule as that applied to the right and left banks of a river.

In Fig. 2, the touches are inserted as if the slopes were uniform between the contours, but as such might not be the case, this step of the work, as well as the shading, should be based on an inspection of the ground, so as to place the touches closer or wider apart, and thus express the minor undulations of the ground; inserting half contours at the lower angles as a further assistance, as exemplified at the summits of the features in Plate II.

A little practice on a few simple examples, gradually combining more difficult features, will soon enable any one to gain a knowledge of this style, but it is recommended that the use of "guiding lines," carefully laid down according to rule, should be adhered to closely at first. This will apply equally to the practised draughtsman and to the beginner; the former will find that he has to break himself of many tricks that he has acquired in free sketching, obliging him at first to submit to an irksome process, but which in the end will emancipate him from any of his difficulties, without retarding his rapidity of manipulation; and the latter will meet with a most useful and unexpected assistance.

Reconnoissance.

So much has been written on the subject of rapid sketching in a military reconnoissance, and writers have so frequently described the process they recommend as the most simple and expeditious, that originality in any proposal that may be made here is out of the question; suffice it that the writer of this paper has a common object, which is to suggest a practical system by which operators may survey and sketch in the field a representation of the ground in its artificial and natural details, with a greater approximation to truth, as regards the latter, than has been heretofore attained; and by which, when thus instructed, and using an uniform scale of shade, they can combine their work without transferring it, thus producing in a very short time a faithful representation in plan of any given area of ground.

Example.

For the sake of description we shall suppose a number of operators who have acquired, first, the use of the prismatic compass and the usual mode of sketching rapidly by sight, with the assistance of a few observations, the artificial features and principal points of importance on the surface of a country; secondly, the mode of laying down the position of contours in a few section lines, already described, and thence, by the same process fixing the relative heights of the prominent features, as a basis upon which to sketch in the contours; thirdly, in the use of a scale of shade applied to these contours as each feature is completed on the ground, assisted by inspection of its various minor "accidents"; and, fourthly, to pace nearly uniformly, that is to say within the limits of 31 to 33 inches.

These operators being under the direction of a superintendent, with assistants if necessary, would be organised to work in the following manner. The country to be reconnoitred being defined, the magnetic bearing of a line drawn through its greatest length would be ascertained, and the work be divided by equi-distant parallel lines at right angles to it; each portion or strip thus bounded being the task of one or two of the surveyors. Frequent exceptions might occur. It would be always desirable, if in presence of an enemy, that these strips of ground should be nearly perpendicular to his front, and the breadth of each strip would vary with the nature of the country.

As the size of objects and features to be represented in plan decreases with the scale, we may assume that the average breadth of each strip may be 3 inches on paper, representing 1 mile in a scale of 3, $\frac{3}{4}$ in one of 4, and $\frac{1}{2}$ in one of 6 inches to a mile; as there are very nearly 2,000 32-in. paces to 1 mile, the strips will be 2,000, 1,500, and 1,000 paces in width respectively.

Supposing the ground to have a front of 6, and a depth of 4 miles, and that it is required to shew it on a scale of 4 inches to one mile, it will be divided into eight strips 1,500 paces in breadth, to each of which two operators would be told off to work together, one as the surveyor, the other as assistant. The surveyor will have pointed out to him the extremities of the base from which he is to be started, and furnished with the bearing of the direction in which his task lies, which will be perpendicular to the base. For this purpose his paper (vide Plate I) should be 8 inches broad and 16 inches in length, divided lengthwise by two lines, xy, $x'y'$, into three columns, two of which, *a* and *b*, will be 3 inches, and the other *c*, 2 inches broad. Upon the middle column the drawing will be executed, and the outer columns, *a* and *c*, may be used during the progress of the survey to fix any points in the neighbouring portions. When the work is completed *a* will be attached to and covered by *b* of the sheet on the left hand; similarly *b* will be placed on and attached to *a* of the sheet on the right, cutting away *c*, except where emergency compelled the surveyor to trespass on and sketch-in any of his neighbour's task.

Having the bearing of his marginal lines xy, $x'y'$, he will lay down the magnetic east and west lines in a few places on the paper, it being unnecessary here to rule them as close as is usually done.

He will select a conspicuous point towards or beyond the extremity of his work, and place himself by a bearing so that the line AB, from him to it, is parallel to the margin. Having ascertained his position A in the base yy' and drawn it on his paper, he will commence work, pacing along the line AB, and occasionally verifying his position by observing on the guiding point, and when he has lost sight of that, by a bearing on some point he has previously marked as being in line with it, thus keeping in the line marked down on his paper. Obstacles will sometimes intervene to prevent his pacing, but they will be only occasional, when he can traverse round them or measure the distance by observations across them without much retarding progress. And to correct the error when pacing over steep inclinations, he will construct a table shewing the differences in paces between hypothenuse and base for any distance.

Before commencing, he must assume some datum level from which to number his contours, selecting what appears to be the highest or lowest ground within view; but if in difficulty he may assume his starting point as zero, and thence number his contours above and below it, distinguishing one or other set by a dash. There is no necessity for his contours to have any individual connection with his neighbours', as in rapid work the hachures will obliterate the contours, and if the inclinations are correct the work at the margins will correspond.

Being well practised in the size and amount of detail to be inserted on the scale he is working with, the surveyor, as he proceeds, will fix all such points by observations, from his initial line, and by perpendiculars formed with the aid of a pocket prismatic square (vide Plate III, Fig. 12), employing his assistant to take them. He will observe with a protractor and plumb-bob the inclinations of his initial line, marking in the contours which cross it by the aid of his scale of shade, and when the features are small, inserting half-contours and numbering them as such, carefully sketching in water-courses and water-shed lines; as he fixes each knoll or eminence, observing the angle of elevation to it, to get its height in contours; and whenever he sees a slope in profile, holding his protractor sideways in line with it, to get its angle of inclination (vide Plate III, Fig. 2). As the detail of each feature, or group of features is completed, and the contours sketched, he will shade in the hachures as already described, leaving his assistant to stand at the point of departure from his line, whenever he is obliged to quit it for this or any other object.

Beyond this, the writer presumes his readers to be acquainted with the usual mode of proceeding in making rapid sketches and filling in the detail at sight, with the simplest rules for conventional signs, and the devices to be resorted to in thickly wooded ground.

It will be readily understood that according to the care with which each man adheres to and measures the length of his initial line, so his work will fit accurately to that of his neighbours. On the largest scale proposed to be used, viz., 6 inches to 1 mile, a divergence of 10 paces to one side or another will only measure in plan $\frac{1}{33}$rd of an inch, and such a divergence is only likely to occur when he has to resort to a bearing to recover his original alignment.

Again, on the same scale, an analysis of the extreme error that might arise from a difference of 2 inches in the length of pace of two operators, results in ·375 of an inch per mile, or 1·5 inches in a distance of 4 miles; but practice proves that with men well trained in pacing, such a discrepancy will not arise; and it is moreover quite within the range of possibility that a simple mechanical means of measuring the initial lines might be used.

Rate of progress.

An experienced writer on the subject has estimated the rate of eye-sketching without instruments at about $\frac{3}{4}$ square mile per hour, to which he adds another hour per mile for putting together the information and sketches thus obtained, and making a fair copy. It is estimated that in a sketch made in the way already described, the surveyor will be able to cover about 12 square inches of paper per hour, that is to say, that in the sketch illustrated, the surveyor will advance at the rate of 1 mile per hour on the initial line, producing a far more accurate representation of the ground than could be obtained by eye-sketching, and completing his task in four hours; to this must be added, two hours for the superintendent and his assistants to collect the sketches, to fit them to one another in the presence of the surveyor so that they may be able to account for any errors or discrepancies that may arise, to carry them to head-quarters, and to attach them to one another. After which, when laid out on a board, one or two of the assistants would ink in the principal detail in about one hour, writing on the face of the sketch, or on a report sheet if necessary, any remarks which would be of use to the commander, the result of the observations of the superintendent and his assistants during the progress of the survey; making seven hours altogether from the time when the party arrived on the ground to the time the sketch was placed in the hands of the General.

Many objections may be raised to this mode of proceeding, and it may be said that rules cannot be laid down for carrying out an operation of the nature of a rapid sketch; but the writer calls on those who are sceptical to try what may be called "straight line sketching," and, he thinks, they will find that the exceptions to its practicability are not frequent, and its simplicity, as in land surveying, is undoubted. In the example described it would devolve on the superintendent and his assistants to place the surveyors in the best position on the base of their task from which to start, and to point it out to them on their paper, and to give them the bearing of their initial line; it remaining with the latter to preserve and measure their alignment correctly, and sketch in to the distance of their margins on either side of it.

If questioned as to whom he would employ as surveyors and their assistants in a corps organised to carry out such a nature of reconnoissance to a larger or smaller extent, the writer would reply that he has not the smallest doubt that there are a number of soldiers in the Corps of Royal Engineers who are quite capable of learning a mode of sketching and representing ground so mechanical as that proposed, and, after sufficient training, of producing a combined sketch under the direction of competent officers.

The prismatic compass.

The prismatic compass being the instrument that can be most advantageously used in military reconnoissance, it is requisite that a few remarks be made about its construction.

Little has been done to it since Schmalcalder first introduced it to this country, and any alteration of the present form does not appear necessary. The French in the "boussole Burnier" and the "boussole de poche" have made some alterations, and added a balanced graduated arc to serve as a clinometer or level.

The only drawback to its use in the field, viz., its liability to be affected by local attraction, is, the writer thinks, greatly magnified. In India, he only once found his use of it interfered with, and that in a very few spots on a range of hills to the south of Gwalior, well known for the magnetic properties of their soil. And we find the French using it entirely, either by itself or attached to the plane table, for reconnoissance and rapid sketching.

On the above account, and from its liability to get out of order, officers have often laid it aside and resorted to the use of the sextant, thus losing the great advantages to be derived from observing to a fixed meridian. To obviate this and enable officers to feel safe in depending alone on the prismatic compass, the writer offers his experience in the best way of keeping it in working order, together with some slight alterations in its construction.

It will be seen at once that the parts which require most attention, are the magnetism of the needle and the efficiency of the point on which it rests; but with these in the most serviceable order, the free play of the card will be often prevented by a roughness of surface of the agate bearing. Needles are frequently made too light, and cards heavier than necessary. Mr. Stanley, of Great Turnstile, Holborn, constructed a compass of which the needle weighs 45 grs., the head 15 grs., and the card 12 grs., which works admirably; and he also substituted a graduated aluminium disc for the card, which with the necessary alterations reduces the total weight to 64 grs. But a further improvement might be effected in the form of the needle itself, which has retained, in the prismatic compass, a shape which electricians have long ago discarded. The best form in a galvanometer is rectangular, (with a whalebone pointer of greater length attached, which is found to answer better than a large needle) the unity of the pole depending more on the homogeneity of the metal than the form of the point.

We find that the inertia to be overcome decreases with the load on the needle, and that as the friction at the bearing decreases with the weight, the oscillations are prolonged; on the other hand, the shorter the needle the sooner it settles down, but limited in its constancy by the amount of weight it has to carry: hence by experiment the best form is a needle 2·25 in. in length, ·25 in. broad in the middle, and ·125 in. at the points, weighing 30 grs., and carrying a graduated disc of the lightest construction possible—10 grs., and attached to a head weighing 20 grs.

As a further precaution, a spare needle should be carried embedded in a card-board case (Plate III, Fig. 10) with a piece of bent soft iron let into it so as to touch the needle at each end only, and thus keep up its magnetic properties in the event of the proximity of any disturbing causes. To facilitate the exchange, the brass head containing the agate cup should have a cut in it to receive a turnscrew.

Again, the point on which the needle plays, so frequently gets blunted, broken, or bent, that Mr. Colbrook, the modeller at the Royal Military Academy, has proposed the adoption of thick sewing needles, from which a piece long enough can be broken off and kept in its place by a small brass cone, trisected, which grasps the base of the point in the centre of its segments, and is tightened and held by a collar which screws into a screw-bed, soldered to the compass box, (Plate III, Fig. 11) thus enabling the owner to replace the point from a packet of needles whenever necessary.

Lastly, contained in a pocket attached to one side of the leather compass case, and similar to one containing the spare needles on the other, should be a small implement, having, a flexible blade like that of a palette knife, with which to lift the brass ring which keeps the glass of the compass in its place, a key with which to unscrew the collar containing the point-holder, and a turn-screw to fit the screws of the instrument. (Plate III, Fig. 8).

Officers on service frequently have a breast-pocket into which they put their compass while not using it, but a carrier is preferable, consisting of a short strap to buckle round the neck with a smaller strap attached, which is passed through the prism-keeper and buckled, (Plate III, Fig. 7), letting the compass hang against the chest about five inches below the chin, where it is as safe as when in a pocket, allowing the observer to plot his observations successively, without losing time, care being taken to put the needle card out of gearing.

Sketching cases.

As convenience of carriage, steadiness of surface, and safety of paper, are very desirable in a sketching case, the writer has turned his attention to the subject, and by adapting the advantages possessed by some of those in use, has produced one, which he believes, answers most purposes, is of a durable construction, and allows of the free use of the hands. In the illustration given (Plate III, Fig. 9), it is formed as a sabretache. The frames to hold the paper are of tin japanned and hinged with brass; the board is covered with leather and riveted to the under frame, with an ample pocket at the back; the flap which carries the ornament may be shaped like a

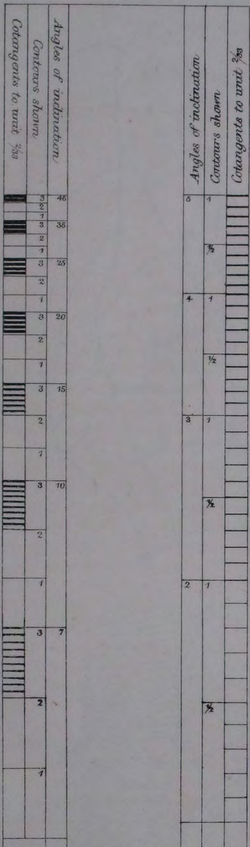


Table of Dimensions in Decimals of an Inch

Angles	Cotangents to unit 2/33	Number of spaces into which contours are divided: Number	Number of spaces into which contours are divided: Dimensions	Thickness of hachures
45	·06	2	·03	·025
35	·087	3	·029	·021
25	·129	4	·032	·0175
20	·166	5	·033	·015
15	·226	6	·037	·0125
10	·344	9	·038	·0105
7	·493	10	·049	·0085
5	·693	10	·069	·0075
4	·866	10	·086	·006
3	1·16	10	·116	·004
2	1·735	10	·173	·002

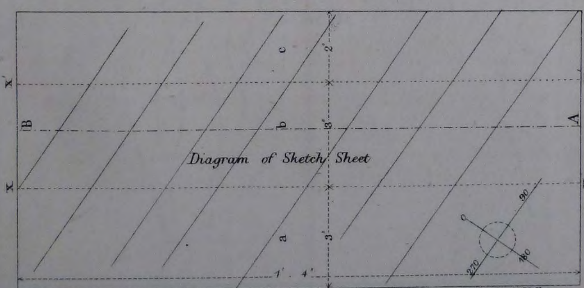


PLATE II.

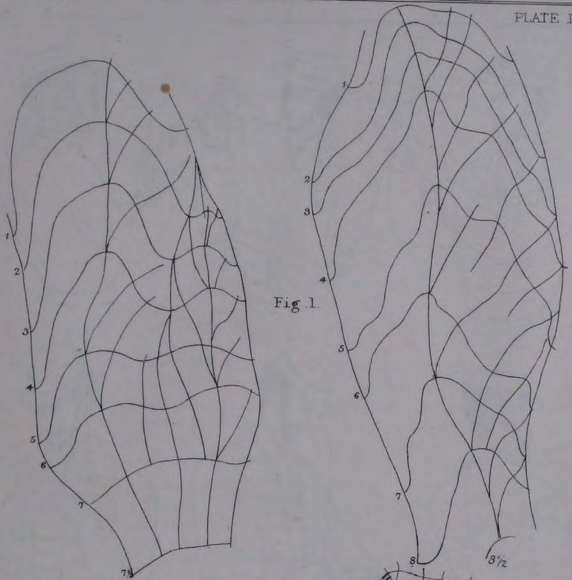


Fig. 1.

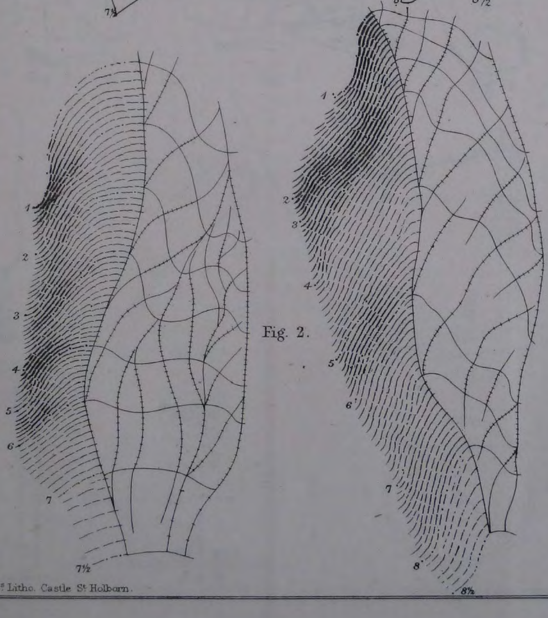


Fig. 2.

Kell Bros. Litho. Castle St. Holborn.

PLATE III.

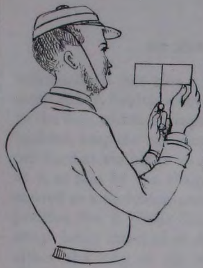


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4

Fig. 5

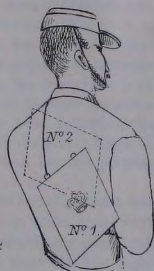


Fig. 6.

Fig. 7.

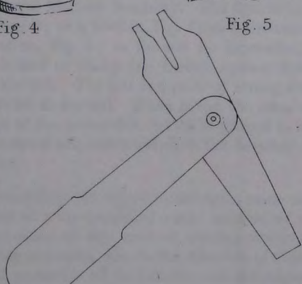


Fig. 8.

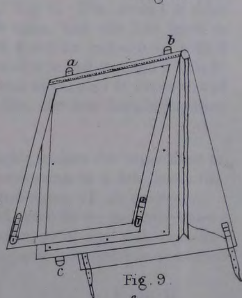


Fig. 9.

Fig 10.

Fig. 11.

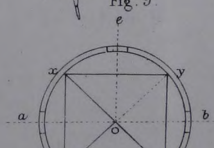


Fig. 12.

Kell Bros. Litho: Castle St. Holborn

sabretache, it has also a pocket, which is divided into compartments for the small stores, having a cover buttoned over the opening; two straps are attached to the flap, which correspond to two small buckles on the upper frame, and when buckled, keep the case shut, and press the frames together. Two rings *a* and *b* are fixed at the hinge so as to carry it as a sabretache, and a third ring is fixed at *c*, so that by the slings being joined and attached at *b* and *c*, it may be carried as a sketching case; while walking, in position No. 1; while riding, in position No. 2 (Plate III, Fig. 6). Fig. 5 gives its position while in use, the strap being attached at opposite corners enables the sketcher to turn it with either the long or the short side towards him, a decided advantage while shading; and, being balanced, the hands may be rested on it as on a table.

The prismatic square. This pocket instrument, which may be constructed nearly twice the size shewn in plan (Fig. 12), consists of a brass cylindrical box, with a ring at the top to hold it by, and vertical slits in it at *a, b, d, e*. It contains two prisms resting on one another, *x y z*, *x y z'*, so that their faces coincide in the plane *x y*, and fitted so as to be capable of accurate adjustment. Therefore, when *y z*, *x z'* are at right angles, the observer *e* is in line with the objects *a* and *b*, which he sees reflected at *o* in the two faces successively; and the rays pass through the instrument at the slits following the directions *a o e*, *b c e*—*y z*, *x z'* being made opaque. Through the fourth slit at *d*, he can see an object directly above or below the prisms, and lay out perpendiculars on either side of a line.

The clinometer. The use of the protractor and plumb as a level and clinometer has been already referred to. It will be sufficient to state that, with ordinary care, it has been found to answer admirably for some time at the Royal Military Academy. The figures in Plate III. show the best mode of holding it; as a level in Fig. 1; as a clinometer, in the right hand for angles of elevation, Fig. 3; in the left for depression, Fig. 4. The second or third finger is used to clamp the thread against the edge, and the free hand to steady the bob. The line is a piece of strong silk about six inches long, with a pistol bullet at one end. When in use, the other end is passed through a hole in the edge of the protractor, which is pierced as near as possible to the centre of the protracted arc, and knotted on the bevelled side, the line hanging against the other.

In concluding, the writer would again press on his readers the importance to a general of a topographical corps capable of producing in a few hours the reconnoissance of any area of country not in possession of an enemy; increasing necessity, due to the adoption of rifled arms, for an accurate knowledge of ground in all its details; and the present want of any such organization to develop the existing resources, which this paper is designed in a measure to describe.

C. E. W.

PAPER IX.

NOTES ON SOME EXPERIMENTS IN BLASTING IN BRICKWORK.

(Demolition of portions of the building erected for the International Exhibition of 1862).

By LIEUT. H. P. KNOCKER, R.E.

The Exhibition Building was purchased by Mr. C. J. Freake, for the sake of the materials, and his men had been for some months engaged in the work of its demolition, when permission was obtained from him, in September, 1864, to make some experiments on the portions not already removed.

These portions were as follows:—

The brick buildings at the ends of the nave, each consisting of two towers supporting between them a large semi-circular arch, which had carried the gable end of the roof. The towers at the north-east and south-west corners of the building, and the great central entrance in Cromwell Road.

The experiments were made under the direction of Lieutenant Colonel Lovell, C.B., R.E.

Demolition of the Arches.

Our experiments commenced with the demolition of the two arches.

The eastern arch was 6 feet wide and 7 deep, but the front face was built in steps, so that the arch consisted of three concentric rings; the upper one 6 ft. wide and 2 ft. 3 in. deep; the middle one 4 ft. 8 in. wide and 2 ft. 3 in. deep; and the lower one 2 ft. 3 in. wide and 2 ft. 6 in. deep. The span was 59 feet. The weight 120 tons. The height of the intrados of the crown above the ground was 76 feet. The super-incumbent brickwork had been removed to within 13 feet of the springings.

It was decided to break through the arch on both sides, and a charge was accordingly placed in each ring, with a fourth charge just behind the arch itself.

They were as follows, for each haunch :—

	L.L.R.		Diameter of Hole.	Charge of (L.L.R.)³.			
	ft.	in.	Inches.			lbs.	ozs.
In Lowest ring.........	1	5½	2½	¼	=	0	12
„ 2nd „	2	3	„	¼	=	2	14
„ Upper „	1	7	„	⅕	=	0	13
Behind the Arch	2	6	„	⅓	=	5	1
					Total...	9	8

The arches were built of ordinary yellow stock-bricks laid in Portland cement; the rest of the buildings were constructed of the same bricks laid in mortar.

The charges were fired with Professor Abel's fuzes and the ebonite frictional machine.

The arch broke into several large blocks, which fell vertically to the ground.

Our working-party consisted of one sergeant and four men. The average boring was 11¾ feet in a day of 10 hours.

The western arch was similar to the above, only that it was half-a-brick narrower. It was demolished in the same way with equally successful results.

It was proposed to demolish the arches by one large charge in the place of the four small ones, but I do not think it would have succeeded, for it was seen in the subsequent experiments that large charges only made a hole of a diameter about equal to the line of least resistance, and threw the bricks to an inconveniently great distance.

DEMOLITION OF THE BUILDINGS.

No. 1 Tower.

The four buildings which supported the arches were all similar, only those at the west end (Nos. 3 and 4 towers) were 13 feet higher than those at the east end, the latter having a height of 64 feet. The front wall was 6 feet thick and the back and side walls were 3 feet 2 inches in thickness.

The abutments on which the arches rested, were in continuation of the front walls of the towers, and each was 17 feet long and 6 feet 6 inches thick.

In the first tower the side walls were cut through over the openings in it, in order to throw down the back wall by itself.

The charges were at three-lined intervals, and each was equal to ⅝ $(l.l.r.)^3$, but the distance apart was too great, and we merely blew holes through the wall.

Four more charges were fired without success, and, on firing yet another four, the wall fell, none of the bricks being scattered to more than 20 feet on either side of it.

It is, moreover, worthy of remark, that the concussion and shock felt in the neighbourhood by the fall of this wall, and even by that of the towers which were afterwards thrown down *en masse*, were trifling, compared with those caused by pushing over a small wall 20 feet in height; as when blown down, the walls crumbled instead of falling flat. Our working party was now increased in number to 1 non-commissioned officer and 12 sappers.

The front of the tower was only about 12 feet distant from the road, so we were anxious to make it fall in the opposite direction. I thought this could be effected by firing the charges under the side-walls before those under the front wall, so that the former being under-cut and hanging on to the latter, would pull it over backwards, when the charges under it were fired.

The charges were now placed at two-lined intervals, and each was equal to $\frac{1}{3}$ $(l.l.r.)^3$ in lbs.

They were fired with Bickford's fuze, and only made holes through the walls, so that the side walls not being under-cut acted so as to prevent the front wall from falling backwards. The greater part of the front wall, when we fired the other charges, accordingly fell into the road dragging with it one side wall. Part of it did not fall, as the abutment wall was subsequently found to be cased, and the charges blew out to the weaker side. To remove the rest of the tower, we placed four bags of powder, containing from 3 to 5 lbs. each, against the parts of the side-wall, between the holes, and covered them with six feet of rammed earth. On firing these, the front wall fell over into the road, in which direction it was already leaning, and the side-wall tore away from the front wall and fell end wise into the building.

No. 2 Tower.

The walls of this tower were already bored in the same way as those of the tower last described, but as it was evident that our charges were in that instance at too great intervals, we placed another line of holes, alternating with the holes already bored, 18 inches above them, and driven from the opposite side of the wall.

The charges were thus at one lined interval, and each was made equal to $\frac{1}{4}$ $(l.l.r.)^3$.

It being found that the resistance offered by the angle of the tower, caused the charge to blow away the salient, and not break entirely through the sides, the holes in the corners were bored so that the charges were one-third through the wall from the inside, and the line of least resistance was taken as equal to two-thirds of the thickness of the wall. This plan was recommended by Sir John Burgoyne, and succeeded perfectly. We blew down the back wall first, and it fell very quietly, as if it were folding itself up. Some of the charges under the side walls were next fired. These were in connection with the gun-cotton experiments, and it was not intended that the walls should fall, for the holes under one wall were not all bored. The charges of gun-cotton were of $1\frac{1}{2}$-inch rope, 8 inches long, and equal to one-sixteenth the weight of an equivalent charge of powder. They were rather uncertain in their results. By their explosion, one side wall was almost entirely under-cut, so that it was left hanging on to the front wall, the greater part of which was unexpectedly pulled over by it shortly after the explosion. The portion of the front wall, which was thus pulled over, was 28 ft. long, 60 ft. high, and 6 ft. thick; and the side wall that pulled it over was 14 ft. long, 63 ft. high, and 3 ft. 2 in. thick. The front wall tore asunder over the arched opening.

When the remaining charges under the other side wall were fired, the rest of the tower fell in the same way.

No. 3 Tower.

As before stated, the towers at the west end of the nave were 13 feet higher, but in all other respects similar to those at the west end.

From the results of the last experiment, I thought we might cause the tower to fall by merely under-cutting the side and back walls, without firing any charges under the front wall. The charges were placed as before at one line intervals, and each was equal to $\frac{3}{10}(l.l.r)^3$. We had thirty-three charges for the final explosion, of which only 14 were fired by the first discharge; the next attempt fired twelve more, and these included all those under the back wall, which fell, the side walls breaking through over the openings in them.

We made a third connection and fired the rest of the charges, which left just a few bricks under the side-walls. These were knocked away on one side with a long pole, and then the tower was under the same conditions as was No. 2 when it fell, but it did not move. To assist it we fired four charges, which were put in holes already bored under it.

The charges were equal to $\frac{10}{35}(l.l.r.)^3$ in lbs., but were rather violent in their results. The wall did not fall till about 15 minutes after they had been fired.

No. 4 Tower.

This tower was similar to the last described. Two lines of charges were now placed under the front wall, the first 2-ft. in from the back, and the second 2-ft. behind, and intermediate with the first; each line of charges was at one lined intervals.

The charges under the back wall were fired first; of these, the two corner charges missed fire.

We next fired those under the side walls, which, being entirely under-cut, crushed the brickwork at the corners of the back wall, which slowly collapsed, followed by the rest of the tower; all the charges under the front wall (40 in all) were left to be fired singly or drowned.

From the above it appears that had all the charges in the last tower gone off at once, the weight of the back and side walls together would probably have been sufficient to pull over the front wall.

No. 5 Tower.

This building enclosed an area of $53\frac{1}{2}$ ft. by 45 ft. The front wall was 6 ft., the back ditto 3 ft., and the side walls 14 in. thick. The height of the tower was 60 ft. It contained 148 rods of brickwork. Experiments were made in the back part of the tower, in comparing the relative results of gun-cotton and powder. The charges of the former were a quarter the weight of the powder. The experiments were not very satisfactory, as the gun-cotton did not do its work well, and the powder charges nearly all missed fire. This was probably owing to defects in the fuzes; those used for the powder-holes on this occasion being some which had been in store a long time, and which were not of Mr. Abel's best construction. Moreover, it was afterwards discovered that these walls were hollow in parts, and consequently the effects of the discharge were much lessened.

Previous to final demolition, for which the charges were placed as before, we cut a chase under the front wall, by a series of charges at $1\frac{1}{3}$ lined intervals, placed 18 inches from the back of the front wall near its foot.

We had now two electric-machines. The first explosion of each consisted of only one charge; a second attempt met with the same results. I then saw that the terminal earth-plates were buried in brick-rubbish, which is a bad conductor. We accordingly carried the return-wires to the instruments, and fired again, when the tower fell most successfully.

No. 6 Tower.

The area enclosed by this tower was a square with a side of $44\frac{1}{2}$ ft. The walls were generally 5 ft. thick.

The north wall adjoined the Horticultural Gardens, and the western wall was only 20 feet from the Albert Road, so that it was important that none of the débris should fall in either of those directions.

There was a large opening in the centre of each side of the tower, reaching to within 12 feet of the top, so I determined to throw the tower in four parts, or one corner at a time, leaving the walls above the opening to be broken through as the different corners fell.

The charges were placed so as to leave the ends of the walls whole on the sides towards which they were not to fall; thus, at the south-east corner, the whole of the angle was under-cut, and the north and west ends of the walls were left entire, so that they acted to prevent the fall occurring in either of those directions. The charges were calculated as before, and this plan answered perfectly in all four cases.

No. 7 Tower.

The last experiment was the demolition of the building through which was the great central entrance from Cromwell Road.

The area enclosed was 145 ft. 4 in. by 54 ft. 4 in., the longer side being parallel to the road.

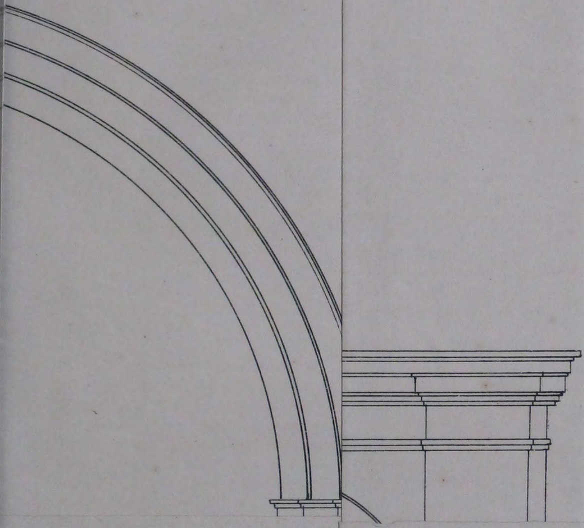
The front wall had a thickness of 6 feet with 14-in. buttresses. The back wall was 3 ft. 2 in., and the sides 2 ft. 4 in. in thickness. There was an internal wall of the same thickness as the side walls, running the whole length of the building at a distance of 16 feet from the front wall, with which it was connected by five cross-walls. Three arched openings, 24 feet in width, crossed the building. The height of the building was 100 feet. It contained 378 rods of brickwork.

A horizontal chase was cut with picks through the buttresses on the exterior of the front wall, and also through the small pilasters, which had supported the

UILDINGS 1862

ONDITION OF

PLATE. I.



flooring girders. At 1 ft. 9 in. from the back of the front wall, and 3 ft. below the level of the chase on the exterior, a line of charges, each equal to $\frac{1}{6}$ $(l.l.r.)^3$, was placed, and fired before the rest. The other walls were bored as before at one-lined intervals, and the charges were each equal to $\frac{3}{10}$ $(l.l.r.)^3$.

As on all the former occasions, a great many of these charges were fired before the final explosion, so as to reduce the number of charges and increase the probability of success.

We had three electric-machines and three series of charges for the final explosion, one, of 62 charges under the internal wall, and two, each of 23 charges, under the back and side walls.

The three machines were discharged at the same instant, when, with little noise or concussion, the building crumbled up and fell into the enclosure: one side wall was stayed for a few instants by a slight support, which was crushed, and it also fell.

The amount of powder employed in the demolition of this building was 174 lbs.

REMARKS.

From the earlier experiments made, it was evident that when dealing with such lofty walls as these, and where there was no lateral pressure, the distance of two-lined intervals for the charges, as recommended by General Sir C. Pasley, is too great. Several experiments were accordingly made to ascertain the exact results to be obtained, and the accompanying sketches of horizontal sections on the level of the bottom of the holes, will shew how imperfect were those results. The charges were fired simultaneously.

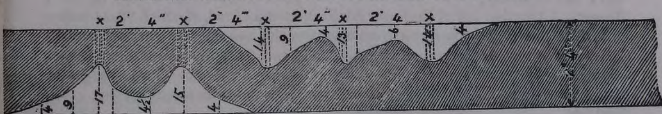
Experiments in Blasting according to General Pasley's Rules.

Thickness of wall = 2′ 4″
Height . . . . = 69′
$l.l.r.$ . . . . = 2′ 1″

Holes bored from the same side at 45°, diameter = 2·4 inches. Depth 1′ 9″, charge $\frac{1}{3} \times (l.l.r.)^3 = 8\frac{1}{2}$ oz.

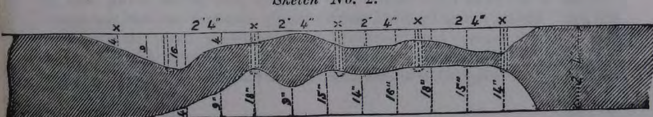
Sketch No. 1.

Horizontal Section on the level of the bottom of the holes.



Similar Experiment.

Sketch No. 2.



Scale $\frac{1}{48}$

In the walls 3 ft. 2 in. thick, charges at two-lined intervals left 18 in. of wall between the holes. Charges at 1½-lined intervals left occasionally 4 or 5 in. of wall between the holes instead of forming a continuous gap, and as it was of the greatest importance for the success of these experiments that every inch of the wall should be cut through, the charges were placed at one-lined intervals.

Boring.

The boring was effected with the ordinary 2-in. and 3-in. jumpers, and hammers.

Our party of twelve was divided into sets of two men, as it was found that more progress was made than when with sets of three, and two men alternately striking. The average depth of boring done in a day of 8 hours was 13 feet.

The holes were bored so that the centre of the charge was in the centre of the wall and were all gauged before being loaded.

Tamping.

Broken brick and sand were usually employed for tamping, and occasionally when time was an object to be considered, sand alone, and it generally stood very well, except when the charges were small compared with the line of least resistance.

Roman cement, not very wet, rammed in alternate layers with broken brick, gave a very firm tamping, and on one occasion was employed with success, when the depth of the tamping was 1 ft. 6 in., and the line of least resistance was 1 ft. 7 in.

On the Mode of Firing the Charges.

The ebonite frictional machine, and Professor Abel's fuzes, were the means generally employed for firing the charges. The machine is the invention of Major Von Ebner, of the Austrian army.

The conducting-wires were of copper, insulated with gutta-percha.

An earth-circuit was generally made use of for the return current, holes being dug for the plates in good earth (when it could be found), and water being poured in to increase its conducting power; but, as seen in No. 5 Tower, there was one failure because the plates were in bad soil, and I fear the same cause may have had something to do with all the charges not exploding at once in No. 3 Tower. Altogether 560 of Professor Abel's fuzes were fired, of which 25, as before stated, were not of the best construction, were old, and did not seem sufficiently sensitive, as the current passed through them and fired those in the gun-cotton charges (which were new fuzes) without affecting them. Two charges in No. 4 Tower also missed fire, the cause of which cannot be accounted for.

Comparison of Cost and Time.

Previous to these experiments, Mr. Freake's men picked down one of the small towers, brick by brick, and he kindly informed me that the operation required twelve men, working for twenty-four days, at a cost of 3s. 1½d. per diem. This gave a total cost of £45, or a cost of 1·8 shillings a thousand, there being half a million of bricks in the tower. In calculating the expenditure, if demolished by powder, I have supposed a chase to be formed under the front wall (as was done in Nos. 6 and 7 Towers) as this makes the result more certain. There would then be in the front wall 45 feet, and in the back and side walls 105 feet of boring, giving a total of 150 feet of boring. Allowing each day two men half a day for sharpening tools, &c., a party of twelve men will bore 72 feet in a day of eight hours. The boring will therefore occupy $2\frac{1}{12}$ days, and adding on $1\frac{11}{12}$ days for loading and firing the holes, 4 days will be the time required to demolish the tower. At the same rate of wages, the cost for labour would be £7 10s. It is stated that an actual cost of 4d. a thousand was incurred in separating the bricks from the large blocks in which the tower fell. This would amount to £8 6s. 8d. The powder, &c., would be as follows:—80 lbs. of powder at 8d. per lb., £2 13s. 4d.; 350 feet of wire, £1 3s. 9d.; 54 Abel's fuzes, 13s. 6d. The total cost would therefore be £20 7s. 3d., or less than one half the cost incurred by the former plan, the operation being performed in $\frac{1}{8}$th of the time. It was stated also that the bricks were injured less when the buildings were demolished by powder. Moreover, it is evident that in the larger towers, the saving of expense would have been in a much greater ratio, as also the saving of time, since when picking down the walls, the cost and time occupied are as the number of bricks, whereas in blowing them down, the cost does not vary as the height, but only as the breadth and length of the building.

H. P. K.

PAPER X.

EXPERIMENTS ON LIMES AND CEMENTS.

By LIEUT. COLONEL GRAHAM, R.E., V.C.

The experiments, of which the following tables give a brief summary, were made with the view of ascertaining what description of lime or cement was best adapted for the concrete revetments in the fort then about to be constructed at Newhaven. The experiments, and the inferences drawn from them, are therefore somewhat of a local character, as it is not pretended to give any absolute verdict on the relative merits of the materials employed *in all cases;* but it is presumed that these tables may be found useful if taken into consideration and compared with some of the valuable tables prepared and compiled by Lieut. Colonel Scott.

TABLE I.—Weights required to crush inch cubes of Cement or Lime Mortar, &c.—April 11th, 1864.

No. of Experiments.	Description of Cement or Lime.	No. of Trials.	Age of Specimen in days. Dry.	Immersed.	Resistance to Crushing in lbs. 2 Sand to 1 Lime or Cement. lbs.	5 Sand to 1 Lime or Cement. lbs.	6 Sand to 1 Lime or Cement. lbs.	REMARKS.
1.	Scott's Cement from Messrs. Rickman & Co...	5	23	...	...	99	...	One specimen failed to bear weight of scales—64 lbs.
2.	Ditto Ditto.........	5	3	20	...	60	...	Specimens broke slowly under weight of scales, ,,
3.	Ditto Ditto.........	5	29	...	...	...	131	
4.	Ditto Ditto.........	5	40	...	420	...	...	
5.	Ditto Ditto.........	10	4	42	355	...	...	
6.	Ditto Ditto.........	6	46	...	448	...	...	
7.	Ditto Ditto.........	5	2	36	274	...	...	
8.	Blue Lias Lime from Stringfield and Blyth ...	8	38	...	110	...	...	
9.	Ditto Ditto.........	8	2	36	56	...	...	Broke easily with weight of scales—64 lbs.
10.	Lias Lime from Chatham	6	30	42	115	...	...	
11.	Hydraulic Lime from Messrs. Rickman (ground)	5	30	42	123	...	...	
12.	Ditto Ditto.........	5	72	...	134	...	...	
13.	Alciston Grey Lime	4	72	...	78	...	...	Air slacked lime, not equal to first specimen; tried February 3rd. (See below, No. 17).
14.	Portland Cement	5	4	42	...	...	207	
15.	Ditto Ditto.........	8	46	...	...	...	256	
16.	Scott's Cement	3	42	...	393	...	...	Experiments made February 3rd, 1864, in presence of Lieut. Col Scott, R.E. The specimens in Scott's cement were imperfect in form, having been injured in taking out of moulds. The Alciston lime had been air slacked for four weeks, and the specimens were very perfect, as they did not expand in setting. Portland cement cubes, 2 sand and 1 cement, could not be broken with the available weights, *i.e.* 5 cwt.
17.	Ditto Ditto.........	3	5	37	167	...	...	
18.	Alciston Grey Lime......	2	42	...	321	...	...	
19.	Ditto Ditto.........	3	5	37	148	...	...	

TABLE II.—Weights per square inch required to tear asunder joints of Brickwork with Lime and Cement Mortar.
11th and 12th April, 1864.

No. of Experiments.	Description of Cement or Lime.	No. of Trials.	Age of joint when broken.	Breaking weight of joints in lbs. per sq. in.				Actual breaking weight on joints	REMARKS.
				To one part of Cement or Lime.					
				2 Sand.	5 Sand.	6 Sand.	14 Sand.		
			Days.						
1.	Scott's Cement	7	46	32·1	...	...	...	514	Sectional area of joints, 16 square inches.
2.	Ditto Ditto	7	40	27·0	...	...	...	433	
3.	Blue Lias Lime from Stringfield and Blyth...	6	40	10·7	...	...	...	171	
4.	Alciston Grey Lime	2	46	10·5	...	...	...	168	
5.	Rickman's Hydraulic Lime	2	40	10·5	...	...	...	168	
6.	Portland Cement	5	40	...	30·9	...	...	495	
7.	Ditto Ditto	2	46	...	...	28·7	...	460	
8.	Ditto Ditto	3	46	...	...	...	6	94	
9.	Greaves' Blue Lias Lime.	2	11	8·0	...	...	...	126	Experiments (9 to 14), made January 3rd, 1864, in Lieut. Colonel Scott's presence.
10.	Scott's Cement	2	11	14·0	...	...	...	224	Joints bad.
11.	Roman Cement............	2	11	11·3	...	...	...	182	
12.	Alciston Grey Lime	2	11	17·5	...	...	...	280	Lime air slacked for 4 weeks. (See remarks No. 18, Table I).
13.	Blue Lias Lime from Stringfield and Blyth ...	2	11	10·5	...	...	...	168	
14.	Portland Cement	2	11	23·6	...	...	...	378	The bricks in these experiments (9 to 14) were of a non-absorbent character.

TABLE III.—Weights per square inch required to tear Moulds of Lime or Cement in Mortar asunder.

No. of Experiments.	Description of Cement or Lime.	No. of Trials.	Age of Moulds. Days.		Breaking weight of Moulds made with 1 part of Cement or Lime to						Mean area of fracture in square inches.	REMARKS.
					2 Sand.		5 Sand.		6 Sand.			
			Dry.	Immersed.	Mould. lbs.	Sq. in. lbs.	Mould. lbs.	Sq. in. lbs.	Mould. lbs.	Sq. in. lbs.		
1.	Scott's Cement	2	46	...	307	135·5	...	...	...	...	2·265	
2.	Ditto Ditto	3	31	...	...	...	...	...	83	41·5	2·0	
3.	Ditto Ditto	2	40	...	244	122	...	...	...	...	2·0	
4.	Ditto Ditto	1	1	30	40	20	...	...	...	...	2·0	Fracture sound and hard.
5.	Lias Lime from Stringfield and Blyth.	1	1	30	Broke in handling.			...	...	...	2·0	Fracture soft and crumbling.
6.	Scott's Cement	2	10	32	83	36·5	...	...	...	...	2·27	One specimen broke with weight of scales. May have been injured previously.
7.	Stringfield and Blyth's Lias Lime	3	31	...	60	26·6	...	...	...	...	2·25	
8.	Ditto Ditto	2	39	...	97	48·0	...	...	...	...	2·25	
9.	Alciston Grey Lime ...	1	46	...	68	34·0	...	...	...	...	2·0	
10.	Rickman's Hydraulic Lime....................	2	46	...	160	73·7	...	...	...	...	2·17	
11.	Ditto Ditto	1	...	82	Broke in handling.			...	...	...	...	No. 11 was immersed before setting, and was found soft inside.
12.	Portland Cement	2	40	...	...	...	242	105·4	...	...	2·295	One of the specimens of No. 12 did not shew good fracture.
13.	Ditto Ditto	1	10	32	...	...	125	66·6	...	...	2·25	The Portland Cement used in these experiments (No. 12) was of an inferior quality; tested pure after 30 days its cohesion was only 220 lbs. per square inch.
	Specimens of Scott's Cement.											
14.	Lewes(Messrs.Rickman)	2	1	295	269	112·2	...	...	...	...	2·4	Experiments made by Lieut. Colonel Scott, in my presence, 6th Feb., 1864, with cement made from different kinds of lime. No. 17 immersed about 18 hours after preparation.
15.	South Wales' Lias	1	1	309	262	109·2	...	...	...	...	...	
16.	Keynsham Lias	1	1	290	361	150·4	...	...	...	...	...	
17.	Lewes, Grey, Rickman.	1	1	65	80	33·3	...	...	...	...	...	
18.	Ditto Ditto	1	2	63	136	56·6						

TABLE IV.—Experiments with Concrete Bricks, and Moulds of Lime and Cement Mortar.—February 3rd, 1864.

No. of Experiments.	Description of Specimen tried.	No. of Trials.	Age of Specimen. Days. Dry.	Age of Specimen. Days. Immersed.	Breaking weight.	REMARKS.
	Concrete Bricks.				ft. in.	
1.	Portland Cement—10 shingle and grit to 1 cement	1	53	...	Weight of 28 lbs. dropped 3 0	Would have broken with less fall than 3 feet . . These experiments were carried on in presence of Lieut. Col. Scott, Lieut. Col. Graham, and Mr. Wright, Clerk of Works.
2.	Ditto Ditto.........	1	53	...	28 lbs. dropped... 2 0 / 2 6 / 3 0	As all the concrete bricks broke with a weight of 28 lbs., dropped 6 in. in height on a sharp edge, except those made with the Portland cement and* 1 with Scott's cement, the relative superiority of the bricks was determined by careful examination of the fractures.
3.	Blue Lias from Stringfield & Blyth—10 shingle and grit to 1 lime.	1	do.	...	Ditto 0 6	
4.	Scott's Cement (10 to 1)	1	do.	...	Ditto 0 6	
5.	*Ditto Ditto (5 to 1)	1	do.	...	Ditto .... 0 6 / 1 0	
	Concrete Bricks immersed.				cwt. qrs	
6.	Scott's Cement (10 to 1)	1	11	42	Transverse strain of 2 0	
7.	Ditto Ditto (5 to 1)	1	do.	do.	Ditto Ditto... 2 2	
8.	Stringfield and Blyth's Lias........... (10 to 1)	1	do.	do.	Ditto Ditto... 0 1	
9.	Ditto Ditto (5 to 1)	1	do.	do.	Ditto Ditto... 0 2	
10.	Roman......... (10 to 1)	1	do.	do.	Broke in handling	
11.	Portland ...... (10 to 1)	1	do.	do.	Transverse strain of 3 3	
	2 Sand to 1 Cement.				lbs.	
12.	Scott's Cement	1	31	11	Transverse strain of 105	
13.	Portland Ditto	1	31	11	Ditto Ditto 196	
14.	Ditto Ditto	1	42	...	Ditto Ditto 161	
15.	Scott's Ditto	1	42	...	Ditto Ditto 126	

REMARKS (continued).

By independent observations the following was the order of superiority agreed upon:

Concrete Bricks of, viz.,

1. Portland cement, 4 shingle, 1 grit, 1 cement 5 to 1
2. Scott's do. do. 5 to 1
3. Portland, 8 shingle, 2 grit, 1 cement... ... 10 to 1
4. Scott's do. do. 10 to 1
5. Stringfield and Blyth's Lias ... ... 5 to 1
6. Roman cement ... ... 5 to 1
7. Portsmouth Lias ... 5 to 1
8. Roman cement ... ... 10 to 1
9. Stringfield and Blyth's Lias ... ... 10 to 1

The concrete bricks were of the size of ordinary bricks.

The following was the result of examination of other specimens immersed:

Portland (2 to 1)	100	Relative hardness of joints of brickwork immersed to set 62 days.
Scott..... (2 to 1)	30	
S. B. Lias (2 to 1)	15	

Relative hardness of Limes and Cements immersed to set. Observed February 3rd, 1864.

	Assumed value.	Immersed.	
1. Portland (2 to 1) ...	100 ...	12 Dec. 1863	
2. Scott (2 to 1) ...	60 ...	30 Nov. 1863	See remarks Table II on the Alciston Lime.
2. Alciston (2 to 1) ...	60 ...	23 Dec 1863	
3. S. B. Lias (2 to 1) ...	50 ...	30 Dec. 1863	
4. Roman (2 to 1) ...	50 ...	12 Dec. 1863	

Memorandum accompanying Tables of Experiments with Limes and Cements.

Table No. I. Comparing Scott's cement with the blue lias from Messrs. Stringfield and Blyth, the former shews a marked superiority. Taking experiments 7 and 9 on immersed specimens, the relative strength of the two is as 5 to 1 nearly. For delivery at Newhaven, the prices of the two would be nearly as follows, viz., Scott's cement, 10d. per bushel; Stringfield and Blyth's lias, $11\frac{1}{4}$d. per bushel. Portland cement would cost at least twice this sum, and when compared with Scott's, must therefore bear not less than twice the proportion of sand used with the latter. Taking experiments 5 and 14 on immersed specimens, Scott's cement bears 355 lbs. on the cubic inch, against 207 of Portland. Experiments 6 and 15 give 448 lbs. to Scott's, against 256 to Portland. The proportion of the two cements in these experiments is as $\frac{1}{3}$rd to $\frac{1}{7}$th, or as 1 to 2·33, the probable prices being as 10d. to 2s., *i.e.* 1 to 2·4.

Table No. II. In this table the relative resistance to a tearing force of Scott's cement and Stringfield and Blyth's blue lias is as 3 to 1 nearly. Compared with Portland cement in experiments 1 and 7, Scott's cement is as 32·1 to 28·7; but in experiment 2, the Scott's cement (at $\frac{1}{3}$rd) is slightly inferior to the Portland, when the latter is $\frac{1}{7}$th the bulk of the composition.

In the experiments of January 3rd (No. 12), the Alciston lime proved superior to Scott's cement. Alciston is not more than four miles from Newhaven, and supplies an excellent grey lime, which would cost about 7d. per bushel, delivered at Newhaven, unground, or perhaps 9d. ground.

To obtain the results given in No. 12 of Table II. and No. 17 of Table I., the lime had been air slacked for four weeks previously, a condition unattainable with large quantities. With other specimens of this lime obtained direct from the works, I have been unable to obtain such good results (see No. 4, Table II., and No. 13, Table I).

Table III. The great inferiority of the blue lias to Scott's cement is here again apparent. The immersed specimens of Portland cement and Scott's (13 and 6) give a superiority to the former, but one of the specimens of Scott's had probably a flaw, as the other was exactly equal in strength to the single specimen of Portland. In experiments 12 and 3, Scott's cement again shews a superiority over the Portland. The Portland cement used in these experiments was of an excellent description, but that last supplied was found inferior, and the results rejected for comparison with Scott's cement.

The blue lias from Stringfield and Blyth appeared in excellent condition, and, being well preserved in a cask, is now as sound as when first sent. It is much quicker in setting than the Scott's cement or Portland, and expands. It has been tried with hot as well as with cold water, without any perceptible difference in the results. A specimen of blue lias lime was also obtained from Messrs. Greaves, of Paddington, but the results obtained with it were so unsatisfactory, that they were rejected for purposes of comparison, as were also those obtained with some local limes, other than Alciston. The Scott's cement was generally used fresh, and obtained as required from Messrs. Rickman, as it deteriorates by keeping, losing by exposure its cement qualities.

Table IV.

The results obtained from the previous tables are borne out by the experiments shewn in this table. In all the trials with equal proportions of sand and cement the Portland stands first, but with a double proportion of sand, it is inferior to Scott's cement.

I may add that all the specimens were prepared and tried under my personal superintendence.

G. GRAHAM,
Lieut.-Colonel, Commanding Royal Engineers,
Brighton, April 17th, 1864.

PAPER XI.

GUNNERY EXPERIMENTS UPON IRON ARMOUR.

BY CAPTAIN INGLIS, R.E.

The following account, in continuation of Paper XVI in last year's volume, completes the subject of experiments upon iron armour, up to the summer of the present year (1865).

In connection with this will be found, at page 9, the tables promised in the concluding paragraph of the paper above mentioned. Although these tables are not made up to quite the present time, yet there would be little to add on account of this year's experiments, and that may be supplied from the following matter.

Spherical steel shot against $5\frac{1}{2}$-in. plates, unbacked. 28th Nov., 1864.

The first practice to be noticed was with the 68-pr. service and the 100-pr. smooth bore wrought-iron experimental gun of $6\frac{1}{4}$ tons, at Shoeburyness, to test shot made of various kinds of steel. The shot were supplied by the following makers, viz., Sanderson & Co.; Marsh, Brothers; Firth & Sons; Naylor, Vickers, & Co.; Cammell & Co.; Bessemer & Co.; Heintzmann & Co.; Attwood & Co.; and were all spherical. The plates fired at were all 7 ft. 6 in. long, 3 ft. 6 in. wide, and $5\frac{1}{2}$ in. thick. They were rolled at the Millwall Iron Works, and were fixed vertically, without backing, against a wooden frame, and held in their places by means of the railway rails and shackles described at page 139, Vol. XIII.

The range was 200 yards, and the charges used were 16 lbs. with the 68-pr., and 25 lbs. with the 100-pr. gun.

The velocity on impact was 1,380 ft. per second in the case of the 68-pr. shot; and 1,500 ft. in that of the 100-pr.

The greatest result obtained from the 68-pdr. gun was with a shot of Messrs. Sanderson, which weighed 73 lbs., its diameter being 7·88 in. It made an indentation of 3·675 in., and remained sticking in the plate with 4 in. out. A piece 12 in. by 15 in. scaled off the back of the plate. The shot was cracked, and pieces were broken off. Its greatest diameter after firing was 8·19 in., and its least 7·25 in. The vis viva in this shot at the instant of impact was about 964 tons raised 1 foot high, now commonly called *foot-tons*, which expression will also be used in the remainder of this paper. Other shot had nearly as much effect, the least indent in 17 rounds being 2·15 in.

Nearly all the shot from the 100-pdr. pierced the plates, and buried themselves in an earthwork in the rear. These shot weighed from 101 to 104 lbs., and their diameters varied from 8·82 to 8·915 in. The average vis viva on impact may be taken at about 1600 foot-tons.

Steel and chill cast shot against the "Warrior" target, 16th Dec. 1864, and 5th and 6th Jan., 1865.

This experiment was to test the relative powers of the 100-pdr. smooth bore wrought iron gun of $6\frac{1}{4}$ tons, and the 7-in. muzzle-loading shunt gun of 134 cwt., throwing steel shot, with charges $\frac{1}{4}$th the weight of the shot, against the "Warrior" target. It was also designed to shew the relative penetration of iron shot cast in chill, on the principle advocated by Major Palliser, and steel shot. The range was 200 yards, and the general results may be stated as follows :—

Steel cylindrical shot with hemispherical heads weighing 100 lbs., $10\frac{1}{2}$ in. long and 6·91 in. in diameter, fired with a charge of 25 lbs. from the 7-in. gun, striking with a velocity of about 1535 feet a second, and having vis viva equivalent to 1633 foot-tons, went completely through the target.

Shot similar in every respect to the above and from the same gun, but fired with reduced charges of 17 lbs. to give a striking velocity equivalent to that produced by a charge of 25 lbs. at 1200 yards, failed to penetrate the target. These shot struck with a velocity of about 1358 feet, which gives a vis viva equivalent to 1278 foot-tons. They buried themselves in the target, so that their base was about 2 in. from the face of the armour ; but in no instance did they damage the skin of the ship.

The steel spherical shot, weighing 105 lbs., 8·7 in. in diameter, fired with a charge of 25 lbs. from the 100-pdr. smooth bore, penetrated into the target until its surface was about $6\frac{1}{2}$ in. inside the face of the armour. The skin was cracked, and the ribs bulged and injured, but the shot remained in the target. The same shot when fired from the same gun with a reduced charge, calculated to give a striking velocity equal to that produced by a full charge of 25 lbs. at 1200 yards, only made a slight indent of 1·7 in. in the face of the armour, and buckled the plate ·8 in. over a length of 4 feet.

Chilled cast-iron shot with elliptical heads, weighing 101 and 102 lbs., 12·34 in. long, and 6·89 in. in diameter, fired with a charge of 25 lbs. from the 7-in. gun, and striking with a velocity of about 1,480 ft. a second, and equivalent vis viva of 1,549 foot tons, completely penetrated the target. These shot of course broke up.

Shot of similar material, with hemispherical heads, 12·34 in. long, and 6·89 in. diameter, weighing 104 lbs., fired from the same gun, also with 25 lbs. charge, and striking with a velocity of about 1,460 ft. a second, failed to penetrate the target. They buried themselves at a depth of 9 in., measuring from the face of the armour to the base of the shot, and broke up after doing a good deal of injury to the fastenings. Whether this falling off in effect was due to the form of the head of the shot, or to some difference in the quality of the metal of which it was made, was not apparent.

In the nineteen rounds which were fired in this experiment, nineteen armour-plate bolts were broken, only three of which were on Major Palliser's plan, notwithstanding that more than two-thirds of the number of rounds were fired at that part of the target where his bolts were solely used.

Steel-pointed Projectiles for the penetration of Iron Armour, 12th Jan., 1865.

This experiment was undertaken at the suggestion of Mr. C. W. Lancaster, with the object of ascertaining the effect produced upon iron plates by steel projectiles with heads slightly concave or cup-shaped, and by projectiles of wrought and cast-iron with points of steel similarly formed and welded on, as compared with projectiles having the ordinary hemispherical or elliptical heads, and made entirely of steel.

The gun used was a 7-in. wrought-iron muzzle-loading rifle, weighing 149 cwt., the target was the "Warrior," and the range 200 yards.

A solid steel cup-headed shot, weighing 137½ lbs., fired with a charge of 17 lbs. of powder, and striking with a velocity of 1230 feet a second, passed through the target without breaking up, as did also a similar shot, fired with 25 lbs. of powder, and striking with a velocity of 1431 feet per second.

On referring to the experiments of the 16th Dec., 1864, and 5th and 6th Jan., 1865, above reported, it will be seen that steel shot with hemispherical heads fired with 25 lbs. of powder from a 7-inch gun, did on that occasion pass through the "Warrior," but when the charge was reduced to 17 lbs., they did not effect penetration, in fact they then did no damage to the skin of the ship. It may therefore be argued that the concave head has some advantage over the convex form, unless indeed, as is probable, the steel used on this occasion was of very superior quality.

The solid shot having cast iron bodies and steel cup-shaped points 4 in. thick, weighing altogether 130·4 lbs., and fired with 17 lbs. and 25 lbs. of powder, did not penetrate the target, and themselves broke up. Similar shot having bodies of wrought iron, and weighing 137½ lbs., similarly failed to effect penetration, and also broke up. Both of these natures of projectile therefore proved themselves inferior in penetrative power to the chilled cast iron shot used in the previous experiments above quoted, and a fortiori much inferior to the solid steel shot then used.

4½-in. plates, inclined at an angle of 38 deg. 26th Ap., 1865.

In the course of the great competitive trial between the Whitworth and Armstrong guns, it was determined to ascertain the relative powers of the 70-prs. upon 4½-in. armour-plates inclined to the horizon at an angle of 38°.

Two plates, each 15 ft. long and 3 ft. 4 in. broad, manufactured in France, by Messrs. Petin, Gandet, & Co., were used for the trial, and were secured to timber sloping frames in such a manner that they were supported only on their edges. The shot from the Whitworth gun were of steel and flat-headed, weighing 71 lbs. 2 oz.; length, 12·66 in.; diameter, 5·46 to 4·98 in.; and were fired with a charge of 12 lbs. The Armstrong shot were also of steel, round-headed, weighing 69 lbs. 12 oz.; diameter, 6·3 in.; length, 9·9 in.; and were fired with a charge of 14 lbs. The range was 200 yards. None of the shot passed completely through the plates.

The Armstrong projectile made a long indent, about 15 in. by 7 in., somewhat deeper than the thickness of the plate itself, and burst the plate open in the impression, breaking off large pieces in rear, measuring as much as 18 in. by 12 in., beside very considerable bulges; in fact, although the shot did not pass through, the plate was completely penetrated and very severely injured.

The Whitworth shot had less effect. The long impressions (about 15 in. by 6 in.) made, were from 2½ in. to 3½ in. deep, in their deepest parts, and there were corresponding bulges in rear, with, in one case, a considerable crack, but in no instance did daylight appear through the plate.

The *vis viva* in the Armstrong projectiles, on striking, was about 1,030 foot-tons, and in the Whitworth about 966 foot-tons.

The Armstrong gun was a muzzle loading gun on the shunt principle.

Hercules target, Shoeburyness. 21st June, 1865.

The only ship's target that has been tried at Shoeburyness, since the small plate target, in August, 1864, is that representing a portion of the side of the "Hercules" at her water-line. As nothing, hitherto designed for floating structures, will at all come up to the strength intended for this ship, the experiment was regarded with more than ordinary interest. The resistance to be expected from the target, seemed, however, to be much undervalued; at any rate the guns used for the experiment were quite inadequate to test its full powers.

The following is a description of the target. It was 18 ft. 2 in. long, by 8 ft. high, and its face consisted of two armour plates of very superior rolled iron, made by Messrs. Cammell and Co., of Sheffield, each 18 ft. long and 4 ft. wide, the upper one was 9 in. thick, and weighed 11 tons 11 cwt.; the lower one was 8 in. thick and weighed 10 tons 6 cwt. The rest of the structure was uniform throughout. The armour was backed by a thickness of 12 in. of timber, laid horizontally, in which were horizontal stringers, consisting of angle irons, 12 in. by 3½ in. by ⅝ in., so placed that each plate was supported throughout its whole length by two of them, at a distance of about 1 ft. from their top and bottom edges. This timber was backed by the main skin of the ship, which was 1½ in. thick in two ¾ in. plates; the joints of the skin plates were strengthened by covering pieces and the stringers, before described, were strongly riveted to the skin by their shorter arms. The bolts securing the armour plates were double-nutted on washers at the back of the skin; each plate was held by 20 bolts, half of which were 3 in. screw bolts of the ordinary construction, excepting the thread, which was rather finer than the "Warrior" thread, and the other half were 2½-in. bolts, on the principle advocated by Captain Palliser and described at p. 136, Vol. XIII. The skin was supported by the main ribs of the ship, spaced 2 ft. apart, there being consequently 10 of them. Each rib was 10 in. deep and was composed of an angle iron, 10 in. by 3½ in., by ½ in., and two angle irons 3½ in. by 3½ in. by ⅝ in. riveted to it. The spaces between these ribs were filled with vertical timbers as thick as the depth of the ribs, that is 10 in. thick. At the back of the ribs came two horizontal layers of timbers, making together a thickness increasing from 1 ft. 3 in. at the bottom, to 1 ft. 6 in. at the top. This timber was not bolted to the main structure of the ship, and therefore formed only a sort of packing; at the back of this was an inner skin, ¾ in. thick, on a second framework of ribs, 7 in. deep, each composed of an angle iron, 7 in. by 3 in. by ½ in. with an angle iron, 3 in. by 3 in. by ⅝ in., riveted to it. There were 9 of these inner ribs, which were also spaced 2 ft. apart, and so placed as to be behind the centre of the intervals between the main ribs; each alternate inner rib was secured at its upper end to a strong iron knee which was attached to the framework of an old ship's target already erected.

The "Hercules" target may, therefore, be said to be a development of the "Bellerophon" target, described at p. 120, vol. XIII; 8 in. and 9 in. of armour being substituted for 6 in. plates, and the backing and framework being proportionally increased in strength, while a supplementary structure, consisting of about 18 in. of timber packing and an inner skin and framework, was added at the back. The ponderous strength of the target will be judged by its weight being stated at 687 lbs. to the superficial foot where the 9 in. of armour was used, and 640 lbs. at the 8 in. of armour, while the "Bellerophon" target, representing the heaviest ship's side yet adopted, weighed only 393 lbs., and the "Warrior" only 341 lbs. per foot superficial. The collected weight of iron in the upper half of the "Hercules" target amounted to about 502 lbs. per foot superficial, and the timber to 185 lbs. In the lower half the iron weighed about 462 lbs., and the timber about 178 lbs. per superficial foot of the face of target. The total thickness of target at the top was 4 ft. $10\frac{1}{4}$ in., and at the bottom 4 ft. $6\frac{1}{4}$ in.

The guns used in the experiments were the 9·22-in., the 10-in., and the $10\frac{1}{2}$-in. rifled guns, each weighing about 12 tons. The range was 200 yards.

The first shot was of steel, cylindical, weighing 221 lbs., fired from the 9·22-in. gun, with a charge of 44 lbs. of powder. It struck the 9-in. armour plate near its upper edge with a velocity of about 1,450 ft. a second. It made an indentation $5\frac{3}{4}$ in. deep, and caused a crack in the plate 9 in. long. The shot was set up about 3·4 in., and was cracked but not broken up. There was no damage inboard, and no bolt broken, but from the position of the blow the information to be gained is not of much value.

The next was a cylindrical steel shot weighing 300 lbs., fired from the $10\frac{1}{2}$-in. gun, with a charge of 45 lbs. of powder; it struck the 8-in. armour plate close to the joint between it and the 9-in. plate, with a velocity of 1,250 ft. a second. It made an indent 8·51 in. deep, including actual impression and buckle over a length of 40 in. The diameter of the shot mark was about 13 in. to $13\frac{1}{2}$ in. Part of the armour in the shot mark was driven just into the wood backing and very nearly detached from the plate. The armour-plates were driven asunder about 1 in. The shot flew back about 16 yds., set up and increased in diameter at its head to about $11\frac{1}{2}$ in. There was no damage inboard and no fastenings were injured.

The third shot was the same as the first. It struck the 9-in. armour with $6\frac{13}{16}$ in. of its longer axis out and made a buckle in the plates of $\frac{1}{2}$ in. over a length of 40 inches. This shot fell out after a subsequent blow on the target, and the penetration was then found to be 4·35 in. There was no damage inboard, and no injury to the fastenings.

The fourth shot was the same as the second. It struck close to No. 3 on a bolt, and on the joint of the two armour-plates, but principally on the 9-in. plate, making an indent of 8·27 in. deep, including actual impression and buckle. It separated the armour-plates a little and did other slight damage, but there was no effect whatever inboard. The shot fell back slightly cracked and a good deal enlarged in diameter about the head, but not broken up.

The fifth shot was of steel, cylindrical, weighing 300 lbs., fired from the 10½-in. gun., with an experimental charge of 60 lbs. of powder. It struck the 9-in. armour-plate, with a velocity of about 1,450 ft. a second, and stuck in it with 6¾ in. of its longer axis out, and probably about 4¾ in. in. The shot fitted as nearly as possible the hole made, the diameter of which was 12¾ in. The original length of the shot was 14·07 in. There was no damage inboard apparent beyond a very slight bulge on the inner ribs. This shot struck very nearly in front of one of the main ribs and just below a stringer.

The sixth shot was from the 9·22-in. gun, with a 55 lb. charge. It weighed the same as No. 1, but struck with a greater velocity of 1,600 ft. a second. It struck in the face of the 8-in. armour, with 6½ in. of its longer axis out, having struck on a bolt. There was a buckle in the plate of 1·85 in. over a length of 40 in., but no apparent damage inboard and no fastenings injured.

After this a chilled cast iron shot was fired from the 9·22-in. gun, with a 50 lb. charge, but it struck the 8-in. plate so close to No. 2 that no reliable results could be noted. It of course broke up, and, with the injury caused by No. 2, formed a large gaping wound in the armour and backing immediately behind it, but there was no injury to be noticed inboard.

This closed the experiment.

The lesson to be learned from it is simply this:—that 9-in. armour of superior quality, backed in the manner above described, is absolutely proof against the heaviest blow that can be given by a 12-ton gun at 200 yards; or, in other words, it will resist the greatest effect that can be produced at that distance by 60 lbs. of powder. How much powder employed to the best advantage it would take to pierce the "Hercules" target is a fair problem to work out. It is to be hoped that experiments will yet be instituted with the 22½-ton gun upon this target, using the heaviest charges the gun will bear, as from these we should undoubtedly obtain important data for future calculations connected with land defences as well as floating structures.

It will be noticed that no shells were used in this experiment; but as the armour was quite able to resist the penetration of the shot, except where two struck very close together, it is not likely that much more effect would have been produced with shell carrying bursting charges of not more than 12 or 14 lbs., which may be considered quite the limit of the capacity of a shell from a 10½-in. gun.

It may be added that on a subsequent examination of this target, when the timber "packing" had been removed, it was found that the internal structure had received the least possible injury from this day's firing.

The main rib behind where the 300 lb. steel shot and the chilled cast-iron shot from the 9·22 in. gun struck so close together, was bulged about 1½ in., and its angle irons were crushed in two places; the skin and adjoining rib were also a little bulged, and a few rivets were broken. Other ribs were bulged slightly, that is from ⅜-in. to ⅝-in., and about a dozen rivets in all were broken. The only point at which the inner skin showed any symptoms of straining was in rear of the 6th shot mark, namely, that from the 9·22-in. gun, fired with a 55 lb. charge, and even here there was nothing beyond a very slight and gradual indentation.

T. I.

PAPER XII.

EXTRACTS FROM RECENT REPORTS OF THE ORDNANCE SELECT COMMITTEE.

Made by permission of the Secretary of State for War.

GROUND PLATFORMS.

QUESTION AS TO PROPER DIMENSIONS AND SLOPES.

Minute 8883. 20th April, 1863.—Read War Office Minute, transmitting a correspondence from Gibraltar relative to the inefficiency of the ground platforms in that fortress, and directing the Committee to report as to the dimensions and slopes best adapted for ground platforms for the several descriptions of ordnance usually mounted in garrisons on such platforms.

It is also submitted that in carrying out any experiments for this object some useful information might be obtained as to the thickness of stone desirable for ground platforms in permanent works of defence.

Minute 9140. 25th May, 1863.—The Committee direct that Colonel Taylor be requested to inform them what platforms he has, and at what slope.

Minute 9212. 3rd June, 1863.—Read letter from Superintendent, Shoeburyness, stating that there are five stone platforms at Shoeburyness, laid down in concrete.

Four are similar in every respect, viz. :—

Length, 18 feet.
Width, 8 feet in front, 13 feet in rear.
Slope—Level for 7 feet 9 inches, rear $2\frac{1}{2}°$.
Composed of blocks of granite from 6 feet to 4 feet × 3 feet and 9 inches thick.

The fifth is also granite, blocks from 6 feet to 3 feet × 1 foot 6 inches, and 18 inches thick.

Length, 18 feet.
Width, 8 feet 8 inches in front and 7 feet in rear.
Slope—level for 7 feet, rear 3°.

He observes that the level portion increases the labour in running up.

Minute 9260. 10th June, 1863.

REPORT NO. 2866.—12th June, 1863.

The Committee recommend that the Inspector of Works be instructed to relay and strengthen two of the ground platforms now at Shoeburyness, which, in addition to others in existence there, will be sufficient to enable the Committee to arrive at a proper conclusion in reference to the question as to the construction of stone platforms generally for the guns most in use.

The platforms which the Committee request authority to have altered are two of the four described in the first part of the preceding Minute.

Judging from the practice at Gibraltar it is evident that in their present state these two platforms are neither long enough nor sufficiently inclined to admit of firing 8-inch guns with service charges.

The Committee, therefore, recommend that the two platforms at Shoeburyness be relaid and strengthened to the following dimensions:

One platform to be level for 7 feet 9 inches, with a slope of 1 in 15 for the remaining length, which is equivalent to a slope of $3\frac{3}{4}°$ nearly. The other platform to have a continuous slope from front to rear of 1 in 15, or slope of $3\frac{3}{4}°$. Both platforms to be 21 feet long, 8 feet wide in front, and 13 feet wide in rear.

Minute 12,191. 15th June, 1864.

Secretary submitted results of trials (16th to 19th May, 1864), of ground platforms of various dimensions, slopes, and thicknesses, with different natures of ordnance mounted thereon.

PLATFORMS.		10-in. gun 86 cwt. Charge 12 lbs.	8-inch gun, 60 cwt. Charge 10 lbs.		40-pr. Armstrong gun, R, 32½ cwt. Charge 5 lbs.	32-pdr. gun, 56 cwt. Charge 10 lbs.		24-pdr. gun, 50 cwt. Charge 8 lbs.	
		Rear chock carriage.	Rear chock carriage.	Common garrison carriage.	Common garrison carriage.	Rear chock carriage.	Common garrison carriage.	Rear chock carriage.	Common garrison carriage.
No. 1. *(a.)*		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
21 ft. long. 1 in 15 slope 9-in. granite blocks	Dry	8 0	7 3	10 6	8 9	5 9	6 9	3 9	6 4
	Wet	10 6	9 6	11 0	9 0	7 0	8 0	4 3	6 8
No. 2. *(b.)* 21 ft. long. 7 ft. 9-in. level, then 1 in 15 slope. 9-in. granite blocks	Dry	10 9	8 9	11 0	10 3	7 0	8 0	4 3	7 9
	Wet	12 0	9 0	11 3	10 3	8 6	8 4	5 9	8 3
No. 3. *(c.)* 18 ft. long. 7 ft. 9 in. level, then 1 in. 23 slope. 9-in. granite blocks	Dry	9 6	9 6	12 0	11 3	6 9	9 6	4 9	9 3
	Wet	11 4	10 0	12 9	11 6	9 6	9 8	6 3	9 0
No. 4. *(d.)* 18 ft. long. 7 ft. 9 in. level, then 1 in 23 slope. 9-in. granite blocks	Dry	9 6	9 6	11 0	10 9	7 0	9 6	5 6	9 0
	Wet	10 6	10 6	11 3	11 6	8 6	9 6	6 3	8 6
No. 5. *(e).* 18 ft. long. 7 ft. level, then 1 in 19 slope. 18-in. granite blocks	Dry	9 4	10 0	18 3*	11 0	10 0	10 0	4 6	9 3
	Wet	12 0	10 3	...	11 3	11 0	10 3	7 3	9 3
No. 6. *(f.)* 21 ft. long. 1 in 15 slope. 6-in. granite blocks	Dry	8 6	7 6	12 9	9 1	6 9	7 6	3 9	6 9
	Wet	9 10	7 6	13 3	8 3	6 0	7 4	4 6	6 4

* Recoiled altogether off platform.

(a.) This platform is preferred. It stands best, recoil is less violent, guns more easily run up.

The front blocks should be fastened by iron ramps, similar to the rear ones. (This applies also to Nos. 2, 3, and 4 platforms.)

When firing at low angles, a wad is required in front of the shot.

(b.) The first sloping blocks are subject to violent strain; the level portion is of no advantage, and increases the labour of running up.

Front blocks should be fastened by iron ramps.

(c.) This platform is not altered by firing, but it is too short.

(d.) Ditto.

(e). Recoil very violent, and the labour of running up very great. This platform is not secured by iron ramps.

(f.) At the 30th round the platform began to sink; two blocks slightly cracked at the junction of the iron ramping; one block cracked across at the 40th round.

Two blocks have sunk in front, where the first violence of the recoil is felt.

REPORT No. 3,369.—4th July, 1864.

The Committee report the results of the late inquiry which has been made with a view to ascertain what general dimensions and slopes are best adapted for ground platforms for the several descriptions of ordnance usually mounted in garrisons on platforms of that nature.

Concurrently with the above investigation it was considered that in carrying out the necessary experiments some useful information might be obtained as to the thickness of stone desirable for ground platforms in permanent works of defence.

With these objects in view, five platforms, varying in dimensions, slopes, and thickness, as detailed in abstract, Minute 12,191, were prepared, and the guns selected for their trial were those usually employed in works of defence, and which are known to be most violent in their recoil.

Five rounds of service charges were fired from each of the guns employed on each of the experimental platforms, and from the results, which are fully set forth in the printed table, Minute 12,191, the Committee have no hesitation in giving their preference to No. 1 platform, which appears to be more durable than the others, and better adapted for the easy management and working of the guns.

The Committee are not aware of such extensive data respecting the recoil of guns on stone platforms having ever before been established in this country, and hope that they will be found of considerable value to officers called on to direct the construction of permanent works.

PONTOONS.

PRESSURE EXERTED BY ARTILLERY IN MOTION ON.

Minute 10,070.—5th October, 1863.

Read War Office letter, forwarding, for Committee's information, a report from the Assistant Superintendent, Royal Carriage Department, relative to some recent experiments at Woolwich, with a view of ascertaining the actual amount of vertical pressure exerted by various natures of field and siege artillery when passing over pontoon bridges.

The experiments were carried on by means of one of the weigh-bridges in the Royal Arsenal, to the beam of which an ingenious self-registering apparatus was so adapted that the additional vertical pressure due to a body moving over the bridge was measured by a scale, previously graduated by experiments.

The experiments have been made with the different natures of guns mounted on travelling carriages with their full equipment of stores, &c., and in all cases they crossed the bridge at the usual walking pace, a mean of three trials giving the result in the following table :—

Nature of Gun, &c.	Greatest weight on the bridge.		Increase due to motion.		Remarks.
	Stationary.	Moving.			
	cwts.	cwts.	cwts.	per cent.	
40-pdr. Armstrong, L. S. 4 pair of horses.	81·5	106·3	24·8	30	
18-pdr. smooth-bored ... 4 pair of horses.	79·3	100·5	21·2	26	
20-pdr. Armstrong, L. S. 3 pair of horses.	46·75	61·75	15·0	30	
12-pdr. Armstrong, L. S. 3 pair of horses.	35·5	53·2	17·7	50	
10-inch mortar, L. S. ... 3 pair of horses.	63·5	93·2	29·7	46	4 ft. 2 in. wheels.
20-pdr. Armstrong, L. S. 3 pair of horses.	44·75	75·75	31·0	70	Mounted on 4 ft. 2 in. wheels, to prove if the high rate of increase obtained with the 10-in. mortar was due to low wheels.

The point of the greatest additional weight was when the gun carriage wheels got fairly on the bridge.

A pair of horses with driver weighed 25 cwt.

EMPLOYMENT OF VERTICAL FIRE.

Suggestions by General Sir John Burgoyne, G.C.B., with regard to Mortars and Bomb Proofs.

Minute 11,392.—30th March, 1864.

Report No. 3,246.—11th April, 1864.

While fully admitting the force of Sir John Burgoyne's observations as to the value of vertical fire, the Committee's experience of rifled mortars, although somewhat limited, tends to show that little or no advantage is to be gained by their use beyond that which is already obtained by that of the ordinary mortar. The first experiment with a rifled mortar appears to have been made in 1853. It was departmental, and the Committee have no record of the result, but it may be assumed to have been unsuccessful. This mortar was of cast-iron, 8 inches in calibre, and rifled in two grooves. It was twice the length of an ordinary 8-inch mortar. This mortar is still in the arsenal. About this time, that is to say in 1854 or 1855, Captain Palliser had a mortar rifled, which is now in the Royal Arsenal, but it was never submitted to the Committee.

The next trial was with a long six-grooved brass mortar, cast specially in 1856.* It was rifled on the saw principle, with a very slow twist, to a calibre of 10·97 inches.

The shells weighed 270 lbs. The Committee have reports of 10 rounds, 3 with 20 lbs. charge, which all broke, and 7 with 15 lbs., two of which broke. This mortar weighed 7½ tons, and would bear being bored up to 11 inches and re-rifled, should the enquiry be resumed.

Here the subject rested until 1861, when Sir William Armstrong proposed a 7-inch wrought-iron shunt rifled mortar, which was tried at Shoeburyness, in 1862-3, with charges varying from 1 lb. to 8 lbs. powder, at 42° and 45° elevation.

The practice, however, was indifferent, not much better than that of a smooth-bored 10-inch mortar; and as the piece thus failed to realize the advantages hoped for, it was laid aside. No experiments have been made with it since March, 1863.

The disadvantages of mortars are these:—they are necessarily very short, compared with guns or howitzers; being fired at a fixed angle, the charge must vary, which causes a variable space in the chamber, and consequently an unequal action of the charge.

The shells having a low velocity and a long time of flight, are much affected by wind and other disturbing causes.

The unavoidable inequalities in their weight and windage, and in the strength of the powder, all produce much greater inequalities of range and irregularities of direction than the same causes do in the case of projectiles fired from guns.

None of these causes are removed by rifling the mortar, and the only remaining cause which would be removed if effective rotation could be given to the shell, is its want of symmetry and homogeniety. Such rotation would also reduce resistance to a minimum and generally promote steady flight.

It is doubtful if it can be effectually given to a long shell by a small charge in a short piece, and it is probable that in such case the twist must be much more rapid and consequently more trying, both to the mortar and to the shell, than under ordinary circumstances.

The Committee will be happy to submit a programme for the experiments that will in their opinion be necessary before an effective rifled mortar is likely to be arrived at. But before doing so, they would suggest that Sir John Burgoyne be asked to consider whether all the objects he has in view may not perhaps be attained by shells fired at much lower angles than 45°, for example, between 20° and 30°, and descending with angles under 40°.

In such case they are inclined to think that a piece of the nature of a heavy rifled howitzer might be so mounted as to command these angles.

It would be longer than a mortar; the elevations, not the charge, would be variable, and there is reason to think that the fire would possess all requisite accuracy.

* Bore 60 inches.

Minute 11,818.—11th May, 1864.

Read War Office Minute, forwarding, with reference to above Report, an additional memorandum from Sir John Burgoyne on this subject.

He remarks that a great deal of service to be performed by mortars can be provided for to advantage by rifled cannon.

He suggests experiments with projectiles fired with low velocities and nearly horizontal, at iron plates placed at an angle of 45° to the horizon, in order to determine what thickness of iron is a sufficient protection against vertical fire.

He also suggests the use of shells longer, and consequently larger and heavier, than the present service shells for short ranges and high angles of elevation only.

He sees no satisfactory substitute for the small Coehorn mortars for use in the advanced trenches during a siege.

Minute 12,297.—24th June, 1864.

REPORT No. 3,365.—1st July, 1864.

The Committee have given their attention to Sir John Burgoyne's observations on their Report, No. 3264, Minute 11,399, in respect to the investigation suggested by him in the direction of improving the range and accuracy of the fire of mortars.

While fully admitting that many of the services for which mortars have hitherto been employed are now provided for with advantage by the introduction of rifled ordnance, Sir John Burgoyne is of opinion that there still remain qualities peculiar to mortars, such as the power of dropping their shells vertically, or nearly so, immediately behind any cover, however high or steep, and the smashing effect of their shells when falling on the roofs of buildings or upper surface cover. In respect to these he considers it desirable to ascertain by actual experiment whether rifled cannon can be made equally efficient. Sir John Burgoyne proposes, therefore, as interesting subjects for investigation :—

1st. To ascertain the course of trajectory from rifled ordnance, particularly the angle of the actual fall of the projectile to the ground, when fired at different ranges, from every 5° of elevation up to 45°;

2nd. By what arrangements of a simple kind in respect to carriages and platforms such ordnance can be fired at these high angles; and,

3rd. What degree of accuracy of fire can be obtained from them at those angles, the ranges not exceeding 1,500 yards.

The Committee fully appreciate the interest and probable value of experiments in this direction, and are inclined to think that as a preliminary measure important data would be obtained by appropriating for this service the 7-inch breech-loading rifled howitzer of 55 cwt., made by Sir William Armstrong, in 1859, which would, however, require to have a carriage specially made, adapted for angles from 10° to 35°. They would propose to try it with small charges; for example, 2 lbs., 3 lbs., 4 lbs., and 5 lbs.; five rounds with each charge at 10°, 15°, 20°, 25°, 30°, and 35° elevation, which, together with 12 rounds for initial velocity, would make a total of 132 rounds. They would propose to begin with firing out to sea at the high angles, and remove to the land range so soon as ranges get down to 1,100 yards. In this part of the programme there would probably be no great difficulty in ascertaining penetration and angle of descent. The facts of these experiments, combined with the observations of initial velocity, would probably suffice to determine the force of impact, penetration, and other data, which have been referred to by Sir John Burgoyne, for all ranges. If the results should be of an encouraging character, the Committee anticipate no great difficulty in designing a rifled howitzer or mortar, with both garrison and travelling carriage, capable of realizing all the same advantages in a form more convenient than the 7-inch howitzer, and which might be brought into the service.

Minute 12,581.—28th July, 1864.

Read War Office Minute, notifying that the Committee are to undertake the experiments enumerated in the foregoing report.

Minute 12,845.—26th August, 1864.

Read War Office Minute, forwarding for Committee's remarks a letter from Captain Key, of H.M. Ship "Excellent," (received through Admiralty), reporting the results of experiments which he has made with a view to determine the vulnerability of iron-clad ships by vertical fire, and also the probabilities of striking a ship at different ranges by such fire.

Eighty-eight rounds were fired from a 13-inch mortar. The boat in which it was mounted had a slight rolling and yawing motion. The spots on which shells struck were ascertained by means of flags placed on staves 10 yds. apart.

Mean Range.	No. of Rounds.	Supposing the Vessel still, end on.		Supposing the Vessel still, and broadside on.	
		Hits.	Percentage.	Hits.	Percentage.
1822 yds.	25	5	20·0	9	36
984 „	38	26	68·4	12	31
809 „	25	16	64·0	7	28

He considers that these experiments prove conclusively that such vessels could not remain at anchor under the fire of mortars, at these distances, unless their upper decks were rendered proof against steel shell.

Minute 14,595.—22nd February, 1865.

The Secretary submits the results of experiments carried on at Shoeburyness with the 7-inch breech-loading howitzer (Experimental, No. 174), fired at high angles of elevation, and with reduced charges.

TABLE I.

Mean weight of common shell 104·75.

Date.	No. of Rounds fired.	Charge.	Elevation.	Time of flight corresponding to Mean Range.	Ranges.			Mean difference of Range	Mean observed Deflection.	Mean reduced Deflection.
					Min.	Max.	Mean.			
1865.		lbs.	degrees.	sec.	yds.	yds.	yds.	yds.	yds.	yds.
12 Jan.	5	2	10	3·70	363	393	378	10·2	2·0	0·0
,,	5*	,,	15	5·43	484	539	517	16·7	5·8	0·6
13 Jan.	5	,,	20	6·92	586	687	640	32·2	4·4	0·5
,,	5	,,	25	8·62	717	790	762	22·8	7·8	1·0
,,	5	,,	30	9·96	752	848	813	24·4	11·0	1·2
,,	5	,,	34† & 35	11·42	825	981	869	44·6	14·2	1·0
,,	5	3	10	4·96	619	657	639	9·2	3·3	0·6
,,	5	,,	15	7·08	884	941	915	15·6	10·2	1·1
,,	5	,,	20	9·14	1114	1136	1127	8·4	16·7	1·6
,,	5	,,	25	11·34	1296	1367	1331	26·8	28·4	2·5
18 Jan.	5	,,	30	Not observed	1489	1566	1558	26·4	39·8	2·6
30 Jan.	5	,,	35	15·35	1615	1705	1660	29·2	27·4	3·1
16 Jan.	5	4	10	6·11	940	967	957	7·0	3·4	1·4
,,	5	,,	15	8·60	1305	1356	1336	14·6	13·0	1·2
30 Jan.	5	,,	20	11·40	1630	1759	1690	30·0	9·5	2·8
,,	5	,,	25	13·89	1923	1963	1947	16·2	15·8	1·0
,,	5	,,	30	16·34	2138	2207	2190	20·4	22·8	3·0
,,	5	,,	35	18·97	2312	2489	2411	47·0	36·8	1·4
16 Jan.	5	5	10	6·84	1200	1334	1268	37·6	7·3	1·1
,,	5	,,	15	10·36	1800	1918	1871	33·6	15·9	1·3
31 Jan.	5	,,	20	13·22	2209	2400	2305	41·4	26·0	2·4
,,	5	,,	25	16·33	2523	2803	2662	93·6	39·2	3·0
,,	5	,,	30	18·66	2838	2954	2885	43·6	55·8	3·4
,,	5	,,	35	21·28	3016	3198	3109	69·2	77·2	4·6

* The means are of 4, one round not having been observed.

† Only 1 round was fired at 34° elevation.

TABLE II.

Date.	No. of Rounds fired.	Charge.	Elevation.	Mean Range.	Approximate angle of incidence when observed.	Penetration.	Nature of soil penetrated.	Length of graze.	Number that ricochetted.
1865.		lbs.	deg.	yds.		inches.		feet.	
13 Jan.	5	2	20	640	21° 54′	12 to 19 and 49*	Gravel soil with loam beneath.	5 to 7½	4
"	5	"	25	762	25° 51′ to 37° 18′	47 to 51 and 90*	Loam & clay.	6¾ to 10	0
"	5	"	30	813	31° 30′ to 32° 27′	52 to 66	Loam & clay with mud beneath.	8¼ to 12	0
"	5	"	34 and 35	869	36° 18′ to 37° 34′	57 to 80 and 16*	Clay with mud beneath.	9½ to 13	1
"	5	3	10	639	12° 12′ (only this one observed.)†	10	Loam & sand.	8	4
"	5	"	15	915	15° 30′ to 27°	12 to 33	Loam.	9 to 12	5
"	5	"	20	1127	22° 30′ to 23° 18′	18 to 48	Loam & clay with sand beneath.	6½ to 9½	
"	5	"	25	1331	26° 30′	30 to 42	Sand.	6 to 8¼	2
18 Jan.	5	"	30	1558	...	38 to 48	Sand.	1¾ to 2¾	0
30 Jan.	5	"	35	1660	...	9 to 20	Sand.	3 to 4½	0
16 Jan.	5	4	10	957	10° 24′ to 12° 30′	17 to 30	Loam.	2 to 10	5
"	5‡	"	15	1336	17° (only this one observed)	9	"Hard ground."	7	3
30 Jan.	5	"	20	1690	...	13 to 21	Sand.	4¼	4
"	5	"	25	1947	...	19 to 23	Sand.	4½	4
"	5	"	30	2190	...	16 to 28	Sand.	4 to 4¾	0
"	5	"	35	2411	...	17 to 31	Sand.	4½ to 5¾	0
16 Jan.	5	5	10	1268	...	12 to 27 and 72‖	Sand & sandy clay.	6 to 11	3
31 Jan.	5	"	15	1871	...	10 to 15	Sand.	Not observed	5
"	5	"	20	2305	...	10 to 20	Sand.	6	4
"	5	"	25	2662	...	22 to 35	Sand.	6 to 6½	2
"	5	"	30	2885	...	15 to 30	Sand.	5½ to 6¾	0
"	5	"	35	3109	...	30 to 41	Sand.	5¾ to 6½	0

* This was in loam. † The others struck on the hard road.

‡ Two not observed, and two penetrated a sand bank, one to the depth of 6 feet.

‖ This was in a bank.

In the case of the shells which ricochetted, the length of the graze was measured horizontally, and in those that buried, it was measured in a sloping direction.

REPORT No. 3,690.—24th March, 1865.

The Committee report the results of the experiments which have been made to ascertain the probable value of rifled guns when employed under circumstances for which mortars have hitherto been used.

The experiment, which is the subject of this report, was instituted at the suggestion of Sir John Burgoyne, and the points to which special attention has been directed are as follows :—

1st. To determine the angle of the actual fall of the projectile to the ground when fired at varying ranges, with a limited number of definite charges.

2nd. To ascertain by what arrangement in respect to carriages and platforms rifled guns can be fired at high elevations, and,

3rd. What degree of accuracy can be obtained from them at those angles. The ranges not exceeding 1,500 yards.

The gun appropriated for this service was the 7-inch breech-loading rifled howitzer of 55 cwt., made by Sir William Armstrong in 1859. It was mounted on a naval sliding carriage and naval slide. Five rounds were fired at elevations of from 10° to 35°, with charges varying from 2 to 5 lbs.

The range, deflection, angle of descent, and penetration into ground, with other particulars, are detailed in the abstracts preceding this Report.

In the absence of any data which would enable the Committee to compare this practice with the results of vertical fire from mortars, they have only to call attention to the remarkable degree of precision which the rifled howitzer affords when fired with small charges at high elevations.

PAPER XIII.

NOTES UPON THE ATTACK OF THE DÜPPEL ENTRENCHMENTS*,

IN MARCH AND APRIL, 1864.

Extracted (by permission) from Articles in the "*Spectateur Militaire.*"

BY CAPTAIN FRITSCH-LANG, FRENCH ENGINEERS.

TRANSLATED BY THE EDITOR.

Description of the Works of Düppel.

The first line of the Düppel defences consisted of ten detached works, seven of which, viz., Nos. I, II, IV, VI, VIII, IX, and X, were closed at the gorge and more solidly constructed than the rest. The interior crest of these seven works had a command of 12 ft., the exterior crest of 10 ft., the thickness of parapet was 15 ft. thick, the exterior slope at 45°; the escarp was a production of the latter slope, no berm having been left in order to increase the difficulties of escalade. The ditch was 15 ft. deep and 15 ft. wide at the bottom, the counterscarp having a slope of $\frac{2}{1}$, and thus making a width at the top of $37\frac{1}{2}$ ft. There was a glacis in front with a command of about $3\frac{1}{2}$ ft., and a slope in prolongation of the superior slope of the parapet. The interior slope was $\frac{4}{1}$, properly revetted; the banquette was 5 ft. wide and 4 ft. below the crest, ascended by a slope of $\frac{1}{3}$, and in some cases even gentler; this very gentle slope, while facilitating the ascent of the banquette, had of course the great defect of much reducing the interior capacity of the works. At intervals along the banquette, steps were laid against the interior slope to permit of troops rapidly mounting to the superior slope at a time of assault.

The artillery fire proceeded from embrasures, each platform accommodating two guns 6 ft. below the crest. The faces were almost all traversed. Along the gorge, a part of the parapet was replaced by a strong barrier, giving access to the work by a bridge across the ditch.

In the interior these seven works were each provided with a blockhouse, having its longer sides parallel to the capital; the walls were formed of posts, and the roof of strong splinter-proof beams, covered with 5 ft. of earth. It was

* In the absence of any account of these operations from our own officers, it is hoped that the following extracts may prove interesting.—ED.

not until the arrival of the Prussians that masses of earth were thrown up against the three sides of the blockhouses exposed to fire. The loop-holes were raised 9 ft. above the floors, the guard-beds being used as banquettes. The longer sides of each blockhouse were connected with the gorge of the work by means of palisades, so that there was a small court-yard between the entrance of the blockhouse and that of the work. Each redoubt also contained two solidly constructed bomb-proof magazines.

The interior capacity of the closed works was very limited, the largest having only 125 yds. of interior crest, and an area of 14,000 sq. ft., from which must be deducted the space occupied by the blockhouse, powder magazines, banquettes, platforms, traverses, &c.

These arrangements were disastrous for the Danes. In the first place the great height of the loop-holes obliged the roof of the blockhouse to be raised so much that the splinter-proofs were level with the crest of the parapet, and the enemy could thus take them as a target for his rifled guns. At the end of a short time these buildings were consequently nothing more than a heap of ruins unable to shelter a single man, and useless even as traverses, for each projectile which struck them caused a shower of wooden splinters more dangerous than even the projectile itself. From this it resulted that as the troops could not, during the cannonade, remain in the works to be guarded, they were obliged to be allowed to retire either into the trenches which connected the works together, or even more to the rear, and thus on the day of assault the enemy had reached the parapets before the Danes had time to regain their posts. Those Danes who did reach the parapets before the Prussians, being enclosed in a narrow and encumbered space, formed a confused and disordered mass, and were nearly all taken prisoners.

As accessory defences, there were palisades, generally fixed in the middle of the ditch, and fraises in the counterscarp. Mines appear to have been thought of, but too late, though the Danish official report says that the necessary mines, in case of abandoning the works, had been prepared under those numbered IV and VI.

Works Nos. III, V, and VII were simple lunettes, closed at the gorge by a palisade. Their profile was weaker than that of the closed works, the command being only 10 ft., the width and depth of the ditches only 12, the details much the same in other respects. They were not provided with blockhouses. Bomb-proof powder magazines occupied their place.

It was not till after the arrival of the enemy that the Danes established a communication between the works composing their first line; after this they constructed a second line, and finally on the Wenningbund flank a communication between the two lines.

The communications between the works of the first line consisted of ordinary trenches of weak profile, strengthened only where batteries occurred. The numerous obstacles made use of were intended to add to their power of resistance. In the first place pits which served as cover for the advanced posts; then fences of iron wire; besides these, and occupying a space of 4 ft. on each side of the iron fences, a line of small pickets; all these, however, are but slight obstacles to a moderately active infantry, although very much in the way of sorties. The same remarks apply to harrows, or planks armed with nails, which, although perhaps useful against cavalry, are in general, and were particularly at Düppel, of no avail against infantry, the Prussians having passed them without confusion. There were also here and there military pits of the smallest possible description, without pickets between them, and so far apart that many officers of the columns of assault doubted if they had crossed any.

The barricade on the Sonderburg road, on the height near work No. V, was very well made and very difficult to remove.

The second line was intended to have had the same profile as the first, but there was no time to complete it. It was composed of works in the form of lunettes, connected by trenches.

The works forming the bridge-head at Sonderburg had the same profile as those of the first line, with the addition of abattis in front of the counterscarp.

The ground itself offered a means of defence which the Danes had reckoned upon utilising, but which, in the end, only served to increase the number of their prisoners, viz., the thick high hedges, called in Sleswig *knicks*, which bound all the fields.

To conclude, the Düppel position was very advantageous, because, while less extended than the Dannewerk, it corresponded better to the means at the command of the Danish Army; because it rested on the sea, where the Danes had the mastery; because it had a good view of the ground in its front; and, finally, because the line of retreat, in case of defeat, was almost secure; it, however, lost much of its value from the employment of rifled cannon, by which it could be enfiladed from Gammelmark, which latter point the Danes should have foreseen.

They may also be blamed for having adhered to too passive a defence; one or two large sorties (too large even) were attempted, but no reconnoissances. and few skirmishes of advanced posts. These latter are the only means of ascertaining the progress of the enemy, and what he is doing; if in the night of the 17th and 18th April, there had been some attempt to reconnoitre the Prussian works, it would have been seen that the 3rd parallel had been unusually widened and provided with steps to its parapet; and hence it could have been concluded that the assault was imminent.

As to the Prussians, one cannot conceive how, after having arrived on the 12th February, and having by the 22nd, at latest, seen the necessity of siege works, they opened the trenches only on the 30th March, and commenced firing from the batteries of attack only on the 2nd April. They may say that their siege train had not arrived; but how, with telegraphs and railroads, can it have required a month and a half to bring up material which ought to have taken only four or five days on the road. The approaches also appear to have proceeded very slowly. Sixteen days were taken to reach the 3rd parallel, and this without the workmen having been once disturbed, or the works deranged. The Danish Artillery fired only at night, and then not upon the trenches but on the batteries; it is known even that the workmen often remained on the reverse of the trench without any attempt on the part of the Danes to disperse them by grape shot, so much did the latter dread drawing down on one of their pieces the fire of the Prussian guns. On the other hand, they had so little fear of sorties, that the heads of the saps were advanced without the trenches in rear being widened and prepared for musketry. Long lines of workmen were often supported by merely a few sentries, the guard of the trenches being far in the rear.

The following description of the siege-works is taken from a pamphlet by Colonel Neumann, Prussian Artillery, who was present at the siege as a member of the Artillery Experimental Commission, a few remarks being added as notes.

Introduction.

The first shots against the Düppel entrenchments were fired from Gammelmark on the 15th March. They were directed against the flank, and the distance was so considerable (2,500 yds. to the nearest work, see plan), that every possible effort was required to produce a satisfactory result. It was not till after the engagements of the 17th March that the Danes were driven within their works, retaining in front only their advanced posts. The siege of the works of Düppel is (with the exception of that of Gaëta*), the first which has been carried on with the aid of rifled ordnance, and it thus differs essentially from all sieges which have preceded it.

Although the works attacked had only dry ditches without masonry escarps or counterscarps, it is nevertheless certain that the experience gained before Düppel will not be without its use in determining the course of proceeding in future sieges.

In addition to other purposes, the main object to be accomplished by the artillery fire was the destruction of the blockhouses and other defences in the intrenchments, and this to such an extent that the garrison necessary for their vigorous defence should be unable to remain in them. As this required a very curved trajectory in the projectiles employed, the fire of the batteries on Gammelmark, which were ready at an early period, was very suitable, as their great distance ensured such a trajectory. These batteries would be, however, far from sufficient for making a suitable preparation for the intended assault; they could be considered only as powerful auxiliaries to the attack.

The part of the works chosen for the attack was the flank resting on the Wenningbund, because looking to the powerful action of our rifled guns it was probable that the support to be anticipated from the Danish fleet would not be forthcoming; also because this flank being once carried, it was reasonable to expect that by continuing to advance upon the Sonderburg Bridge-head, the rest of the works, being cut off from their line of retreat, would be compelled to surrender. Besides this the Gammelmark batteries could reach this part of the works better than any other, while, on account of the form of the ground, the action of the artillery to be used in front of them would be much more powerful than anywhere else. Lastly, if it were possible to keep off the Danish fleet the approaches along the Wenningbund would be easier than elsewhere.

The position of the batteries was fixed at about 1,000 yds. from the works, in order to obtain a trajectory of considerable curve, so as to act effectively upon the interior of the redoubts without too great a reduction of charge. In addition to this a closer position would have tended to neutralize the advantage we possessed over the enemy of having rifled guns instead of smooth bores.

The results shewed that the distance had been wisely selected, for in addition to the effect of the fire on the interior of the works and blockhouses, it was very valuable in destroying the parapets as well as the palisades and fraises. Against

* And also of some of the recent American sieges.—Ed.

the embrasures also the practice was excellent, guns being dismounted after a fashion never attained by smooth bores, even at very close ranges. Nor for this latter purpose was it necessary for the guns to be on the prolongations of the crests or opposite to the embrasures.

The application of the batteries to the ground had been well managed, for it was ascertained after the assault that only their crests were visible from the works, and consequently the fire directed against them had but little effect, though the ground in their front and rear was studded with projectiles. Great advantage was also taken of the thick hedges in laying out the parallels and approaches.

The Gammelmark batteries, Nos. 1, 2, 3, and 4 (containing eight 24-pdrs. breech-loading rifled guns with six 12-pdrs. afterwards added), opened fire at an early period, viz., 15th March. Their fire was from the first much more effective than had been anticipated, and it was stated by prisoners that in consequence of it some of the Danish regiments refused to cross the Sonderburg bridges for service in the works.

Opening of the First Parallel.

Two branches of communication with the rear having been previously established, the first parallel was opened on the night of 29-30 March, for a length of 750 yds., at a distance of about 1,000 yds.* from the Wenningbund flank of the line of retrenchments. In rear of it, and at distances of from 1,200 to 1,350 yds. from works No. I to VI, seven batteries (No. 6 to 12) containing altogether 34 pieces, were constructed. At the same time, on the height between Düppel and Rackebüll, battery No. 13, for six rifled 6-pdrs., was formed at a distance of 1,350 yds. from redoubt No. IX, to which it was nearest.

These works were all executed under the protection of the Gammelmark batteries, and fire could have opened from the whole of the rifled guns, both front and flank, on the 2nd April, but that on that day a number of them were sent away to Ballegaard, where they were formed into two large batteries on the bank of the Alsen-Sund to co-operate in the projected passage of the Sound. In consequence, the cannonade which was opened for the first time against the front of the line at 2 P.M., was reduced to a simple demonstration, intended only to attract the attention of the enemy to the immediate defence of their works, while a decisive blow was being struck by the passage of the Alsen-Sund. This passage, which was intended to have been effected early on the morning of the 3rd April, was not however attempted, for the waves were running 4 or 5 feet high, and, in the opinion of competent persons, the slight boats intended for the operation would hardly have floated with waves

* This distance appears very great in dealing with an enemy so little enterprising as the Danes. Moreover, the opening of the 1st parallel was not an opening of the trenches in the proper sense of the term, the approaches having been commenced on the 26th March. The great loss of time that occurred in all the operations of this siege would have been dearly paid for if the Danes had been less disorganised. Their advanced posts gave no alarm, and the workmen were so little disturbed that by 3 in the morning, in frozen ground, they had finished the task allotted for the whole of the first night.—*French Translator.*

even one foot high. That this bold enterprise might have succeeded under favourable circumstances is clearly shewn by the success which attended as rash a one, viz., the passage of the Alsen-Sund on 29th June.

On the side of the Danes the works were armed (with the exception of some 4-pdr. rifled guns), with about 120 heavy pieces. These included from 15 to 20 rifled pieces, consisting of 4, 18, and 30-pdr. muzzle-loaders on the French system.

False Artillery Attack on the 2nd April and following days.

Our fire opened at 2 P.M. on the 2nd April, and was vigorously replied to by the enemy. An attempt was made to set fire to Sonderburg by means of 40 carcasses from the two 24-pdrs. on Gammelmark. Though the projectiles (with the exception of the first few), fell into the town, the attempt was not successful, probably because all inflammable materials had been removed. Sonderburg, however, was set fire to the next day, but whether by carcasses or common shells has not been ascertained.

Towards evening a large fire was observed in the space between redoubts Nos. VIII and IX and the bridge-head. It was caused by the burning of the barrack upon which the 6-pdr. rifled battery between Düppel and Rackebüll had been firing.

Fire was slackened during the night, but on the morning of the 3rd, when the passage of the Alsen-Sund was to have been attempted, it was vigorously resumed. It lasted, without much result on either side, till the 6th inclusive. The number of projectiles expended on our side was as follows :—

From the short 12-pdrs.	6,005	shells	....	28	Shrapnels.
7-pdr. Howitzers .	5,018	„	....	10	„
6-pdr. Rifled Guns	1,068	„	....	116	„
Total......	12,091	„		154	„

Commencement of true Artillery Attack and position of the pieces.

For this attack which was intended as preliminary to the assault, and which commenced only on the 7th April, the following additional arrangements to those above enumerated were made.

The eight rifled 24-pdrs. and twelve rifled 12-pdrs. which had been sent to Ballegaard were distributed as follows :—four 24-pdrs. were added to the Gammelmark batteries; battery No. 15 was constructed at the west extremity of the Wenningbund so as to command the whole length of the bay, and armed with the remaining four 24-pdrs. This battery was considered all the more necessary as the Rolf-Krake (Danish iron-clad vessel), in a short trip she had made in the Wenningbund in the early morning of 12th March, during an affair of out-posts, could be fired at only from Gammelmark at a very long range, and by taking advantage of some dead water which the battery was too high to command, had cleverly escaped to sea. This new battery, which could also counter-batter redoubts Nos. I and II at a distance of about 3,500 yds., was not completely armed on the morning of the 7th April, when the enemy discovered it and opened upon it a sharp and accurate fire from rifled 18-pdrs., which, by great good luck, destroyed only three sponges. During the night of 6th-7th April, twelve 12-pdr. smooth-bores and four howitzers were withdrawn from batteries 9, 10, and 11, and replaced by the twelve rifled 12-pdrs. from Ballegaard, and by two rifled 6-prs. Battery No. 14, for four rifled 6-pdrs., was also constructed (between Nos. 7 and 8); so that for the front attack, between the Wenningbund and the Sonderburg Road, fire was opened on the 7th April from eighteen rifled pieces and eighteen smooth-bores. Battery No. 22, for four rifled 6-pdrs., had also been constructed near No. 13, for firing on the enemy's position between redoubt No. VIII and the Alsen Sund.

For the artillery attack commencing the 7th April, the following was then the distribution of the ordnance:—

	Rifled 24-pdrs.	Rifled 12-pdrs.	Rifled 6-pdrs.	Total Rifled gun.	Smooth bore 12-pdrs.	Field howitzers.	Total Smooth bores.
Upon the flank at Gammelmark	8	4	...	12	...	...	...
On the shore of the Wenningbund, Batt. Nos. 5 and 15.	4	4	...	8	...	...	...
For the front attack.	...	12	6	18	6	12	18
Between Düppel and Rackebüll	...	...	10	10	...	...	...
	12	20	16	48	6	12	18

On the night of the 7th-8th April, a demi-parallel was excavated at a distance of about 250 yds. from the first parallel, terminated at each extremity by a lodgment for guns,* four 12-pdr. smooth-bores being placed in the left one and two in the right.

On the night of the 8th-9th of April, four mortar batteries (Nos. 18, 19, 20, 21), each for four 25-pdr. mortars, were constructed behind the demi-parallel, for shelling works III, IV, V, and VI. An addition was also now made to the Gammelmark batteries and to those on the shore of the Wenningbund.

There is no doubt that if the fire opened on the 7th April had been kept up unremittingly day and night for 48 hours, the entrenchments would at the end of that time have offered no greater obstacles to assault than was the case on the 18th April. Besides the enemy would have been equally driven from the works and the space in rear, would have had no time to repair damages and

* On the night of the 5th-6th April, two battalions of infantry, forming four detachments, each accompanied by 13 Sappers, drove in the Danish outposts and constructed rifle pits at about 600 yds. from the works. In the night of the 7th-8th the parallel was opened by 1,500 workmen, supported by two battalions of infantry, whose advanced posts were 120 yds., and the supports 80 yds. in front of the parallel to be formed, and the rest of the force behind the flanks of it. The night was starlight, with 3 degrees of frost. Immediately the officers of Engineers commenced placing the workmen, the Prussian Artillery opened its fire, which had been stopped at dusk. The Danes replied feebly from works I, II, III, and IV. By half-past 3 A.M. the work was finished without a single casualty. The supports alone had a few men wounded.

RÜSTOW.—"*La Guerre de l'Allemagne contre le Danemark en* 1864."

replace unserviceable guns, or to execute the works by which he endeavoured for a length of time to augment the defensive strength of his position; and it was doubtless on these accounts that his Royal Highness Prince Frederick Charles had ordered the assault to take place from the 2nd parallel on the 14th April. At the same time it must be remembered that the distance over which the troops would have had to pass was sufficient, on the one hand, to have exposed them to considerable loss, and, on the other, to have allowed the enemy time to bring up his distant reserves. To these last-named considerations is to be attributed the order issued by the King, recommending that the assault should not take place till the construction of a 3rd parallel permitted a closer approach to the enemy's works. He also insisted on the use of strong columns of assault, with large reserves, in accordance with the experience of the Duke of Wellington, who himself one day told his Majesty "that in none of the assaults of entrenchments which he had directed had he ever succeeded, except when he had made use of strong storming parties; and that, on the contrary, he had always failed when he made the attempt with a restricted number of troops."

On the 7th April we had acquired a superiority over the fire of the works, against which our smooth-bores had been previously powerless, and this without suffering any great loss. On the 8th, at day-break, and for a short time afterwards, Redoubts No. IV and VI still kept up their fire; in the course of the afternoon a well sustained fire from No. IX was all that remained. On the 9th April the enemy completely ceased firing. Our rifled 12-pdrs. had entirely destroyed his embrasures, and the parapet of his lines was only a confused mass of earth. There was good reason to suppose that the blockhouses in the works attacked had suffered most, as they had been the principal object of our fire.

The second parallel and its communications were opened on the night of the 10th-11th April,* and the 3rd parallel and its communications on that of the 14th-15th April.† On the 15th April the widening of the 3rd parallel up to 20 feet at the bottom was commenced; this was necessary to provide room for

* The 2nd parallel, resting on the Sonderburg road, extended about 600 yards south of it; it did not extend to the Wenningbund, and could thus be flanked by the demi-parallel behind it. The working party consisted of a battalion of infantry; the guard of the trenches, of three battalions. The Prussian Artillery fired briskly throughout the 10th, ceasing at night-fall. The Danes were satisfied with throwing a few shells during the night. It was not till nearly 4 o'clock, a.m., when the workmen had been for some time under cover, that a sortie of two companies was made from the direction of No. II Redoubt. It was easily repulsed.—RÜSTOW.

† On the 13th April the artillery fired more quickly than usual to facilitate the execution of the 3rd parallel. This was preceded by an attack to drive the Danish outposts from their rifle pits and force them to retire into the works. This being accomplished, three companies of Engineers immediately commenced the parallel by flying sap, and in a quarter of an hour had obtained cover from musketry. The parallel was about 650 yds. long, one flank resting on the Wenningbund and the other on the Sonderburg Road. It was 170 yds. in front of the 2nd parallel, its right flank 330 yds. from redoubts Nos. I and II, its centre at the same distance from No. III, and 500 yds. from No. IV; its left flank was 250 yds. from No. V, and 500 yds. from No. VI.—RÜSTOW.

the columns of assault, which could not have been assembled in a trench only 8 feet wide and 650 yds. long. In addition to this, up to the evening of the 17th April, the communications in rear were being prepared for the reception of a large number of troops, and the most advanced part of the parallel was being provided with steps to permit the ready egress of the columns of assault.

The 3rd parallel could be placed no nearer the entrenchments without exposing the workmen to a very effective fire of musketry, which would have necessitated the use of sapping, and consequently a great loss of time.

As to why the enemy did not endeavour to interrupt the works by sorties (a question which has been often asked), the probable answer is that he could not have afforded the heavy losses which must have ensued.

The artillery on our side was ordered to fire only for some well defined object, both to avoid waste of ammunition and injury to the guns. Each morning the repairs executed by the enemy during the previous night, as well as any new embrasures, were destroyed, especially if it was thought that any gun was concealed behind the latter. Woe to any of his guns which opened fire. They were immediately played upon by several rifled 12-pdrs., and in all probability never opened fire again.

About 30 shots from rifled 12-pdrs., at distances of from 1,800 to 2,000 yds., were expended in destroying the Düppel windmill, which formed a post of observation to the enemy. It also received some fire from Gammelmark at 3,300 yds.

As on the opposite shore of the Alsen Sund the enemy had established batteries for sweeping the space behind the entrenchments, for defending the flank resting on the Alsen Sund, and for protecting the island against any attempted passage of the Sound, we constructed the following batteries to oppose them, viz.:—

At Lille Mölle	No. 23	for 4 rifled 24-pdrs.
At Stabegaard	No. 24	„ 12-pdrs.
Between Stabegaard and Ravenskoppel,	Nos. 25 and 26	each for 4 rifled 12-pdrs.
At Schnabeck Hage	No. 27	for 4 rifled 24-pdrs.
Ditto ditto	No. 29	„ 6-pdrs.

Of the above batteries, those on Lille Mölle could fire in the direction of Sonderburg as well as against redoubts Nos. IX and X; the others could be used against the batteries in the island, or against vessels coming from the Gulf of Augustenburg to help the entrenchments.

The following changes were made in the artillery on the front of the attack, viz., two new batteries, Nos. 32 and 33, in rear of the left wing of the 2nd parallel for 8 howitzers, and No. 30 for four 12-pdr. smooth-bores behind the left wing of the 3rd parallel, all taken from batteries in rear of the 1st parallel. Besides these batteries, No. 31 for two 24-pdrs. was constructed on the shore of the Wenningbund between the 1st parallel and demi-parallel.

The foregoing arrangements were those made on 18th of April for opening fire on the enemy's position, preparatory to the assault, comprising in all 94 pieces of ordnance, disposed in twenty-four batteries; 58 being rifled guns, viz., seventeen 24-prs., twenty-five 12-pdrs., and sixteen 6-pdrs.; and thirty-six smooth-bores, viz., sixteen 25-pdr. mortars, twelve 12-pdr. field guns, and eight 7-pdr. howitzers.

The Danes had meantime kept up but little fire by day. At night, however, they fired continually and regularly against our distant batteries, particularly from redoubts, III, VIII, IX, as well as from Alsen. Their fire produced but little effect.

The proper hour for making the final assault was a subject of much anxious consideration. It was decided, at any rate, not to make it towards dusk or during the night, daylight being considered an indispensable condition. It was at first determined that early dawn should be the time, so that all the preparation might be made during darkness. Against this, however, was urged the fact that in the various skirmishes of the advanced posts which had usually taken place at dawn, it had been found that not only the redoubts, but also the communications, were kept armed with guns loaded with grape. In order, therefore, to get rid of these guns, which the enemy was always in the habit of removing out of reach of our fire; in order, also, to destroy the repairs he had made in the night, as well as to inflict fresh injury upon the works which he would have no time to make good; and lastly, to enfilade the troops in and immediately behind the entrenchments, as well as to force back the reserves to the greatest possible distance—it was finally determined not to assault at dawn, but to wait until a brisk cannonade against the works and the ground behind had been kept up for some hours.*

The troops intended for the assault were assembled in the parallels during the night. The parapets were so high that even by day the assembly of the troops would not have been observed.

Artillery Operations before and during the Assault.

In the afternoon of the 17th and following night our fire had become somewhat more brisk than usual. The enemy also during this night opened a very sharp fire from all his works and communications, as well as from Alsen, without, however, producing any remarkable results. At 4 a.m., on the 18th, his artillery fire ceased, that of the wall pieces taking its place. At the same hour our fire was also increased, and at 9 o'clock had reached its greatest height, particularly along the front of the attack.

One great object was to prevent the enemy's reserves taking post close enough to the works to be able to assist in repulsing the assault. In each rifled battery one piece was told off to fire upon the ditches of the redoubts, so as to destroy the palisades and fraises.

At 10 A.M. the greater part of the batteries on the front of attack suddenly ceased firing to allow of the assault being commenced. The large rifled guns on

* This was an excellent arrangement. The Danes, guided by information they had obtained, had expected the assault would take place on the 18th, and from early morning had occupied the works; the violence of the enemy's fire drove them away, persuaded, that as the assault had not taken place at dawn, the Prussians would, as on the previous day, confine themselves to a vigorous cannonade. The garrisons, therefore, were withdrawn from the works, a few artillerymen and sentries only being left, who also soon after sought shelter in the powder-magazines. It is a curious fact that notwithstanding the number of shells thrown, not one of the magazines was exploded.—*French Translator.*

Gammelmark still kept up their fire, directing it gradually from the first to the second line of works, and when this latter was carried, against the dense masses of the enemy's reserves, as they came up; finally they fired only against Sonderburg. Soon after quarter to 11, the Rolfe-Krake approached the entrance of the bay in order to fire upon our troops, already in possession of the works; she was received by the Gammelmark fire at 3,000 yards; on account of her incessant movement she was very difficult to hit, but as far as could be seen one shot detached an armour plate from her side, another struck between the tower and bridge; a shell struck the bridge and carried away the long-boat; the funnel and tower were also hit several times. From the Danish official report it appears that a projectile crossed the bridge and wounded, or killed, nine men; the total killed and wounded was 20 men, or nearly one-third of the crew. During the fire upon Sonderburg, a mill and laboratory, distant 5,000 yards, were set fire to.

The number of rounds fired from Gammelmark, on 17th and 18th April, was

From eight 24-pdrs.	573 shells	27 shot.
„ four 12 „	270 „	0 „
Total	843 „	27 „

In front, fire was kept up from the flank batteries 10, 11, and 32, against redoubts Nos. VIII and IX, which were annoying the reserves by their fire. Batteries No. 28, 31, and 15 opened against the Rolf-Krake, though at a very long range. Immediately upon the fall of the second line of works, field guns were brought up to open fire on the bridge-head and on the Alsen batteries, and thus to support the advance of our troops toward the capture of the bridge-head. Some field pieces were also brought into the captured works and used against the Alsen batteries. In only two of the redoubts, viz., I and VI, was it found possible to turn the guns upon the enemy; in the other works they had all been spiked.

The number of rounds fired from the batteries in the front attack from the evening of the 17th to the end of the assault (not including the field batteries) was:—

Rifled 24-pdrs.	150 shells	
„ 12-pdrs.	1400 „	
„ 6-pdrs.	719 „	46 shrapnels.
Howitzers 7-pdrs.	640 „	
„ 12-pdrs.	30 „	30 „
Mortars 25-pdrs.	1700 „	
Total	4639 „	76 „

Fire was also kept up from the batteries between Düppel and Rackebüll, &c., against the opposite shore of the Alsen Sund.

The Assault.

Exactly at 10 a.m., the troops destined for the assault, consisting of 46 companies or 11½ battalions of infantry, 5 companies of sappers, and 7 officers, 24 non-commissioned officers, and 120 artillerymen, all under the orders of Lieut.-General von Manstein, drawn up in 6 columns, crossed the parapet of the 3rd parallel. Each column advanced independently upon that one of the six works, No. I to VI, which it was told off to assault. Its head was covered by a line of skirmishers, following close on whom were the sappers and some infantry carrying hatchets, levers, bags of powder, ladders, planks, bags of hay, &c., for surmounting the obstacles which were expected to exist. After these, at an interval of about 80 yards, came the regular storming party, and finally about 120 yards in rear of them the reserves.

As soon as these columns had vacated the 3rd parallel, the Anstein Brigade advanced into it from the demi-parallel, and other troops in reserve also moved forward.

The Danish troops consisted of 8 battalions distributed in the redoubts. The length of the line from Wenningbund to Alsen Sund is 3,300 yds., so that each battalion had to guard a length of about 400 yds. From No. IV to the Sonderburg bridges the distance is 2,000 yds., and just half-way was the camp right and left of the main road. Between this and Sonderburg, about 1,250 yds. from No. IV, the brigade Scharffenburg, 4 battalions strong, was posted in reserve at the commencement of the assault, it being the nearest practicable point. The bridge-head was manned by 3 battalions of the Kauffmann Brigade, the 4th being posted on the road leading from the camp to Apenrade to form a reserve, and the Alsen Sund flank. Besides these 16 battalions there were also numerous reserves in Alsen, making in all 28 battalions and the Guards.

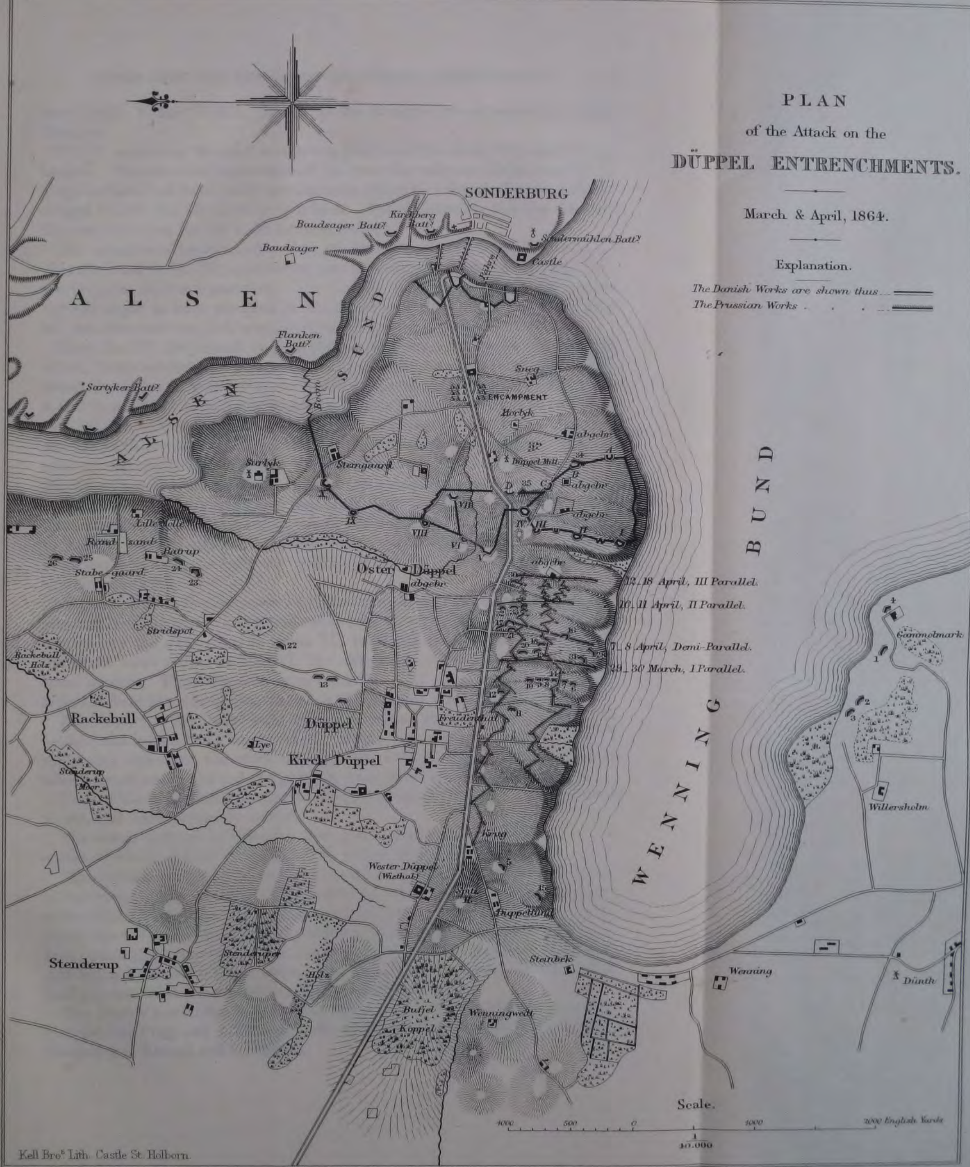
In order to shelter themselves from our fire, the Danish troops who should have been in the works and communications were not everywhere in readiness to repulse the assault; thus, according to the official report, our columns had cleared the parapets of No. VI, when some of the troops for its defence were moving up to cross the bridge at its gorge, and were made prisoners before they had all crossed.

The same thing happened at No. V; and thus in consequence of the proximity* of our 3rd parallel, and the condition to which their works were reduced, the Danish troops were compelled to surrender the position.

Directly the troops left the 3rd parallel, musketry fire was opened on them from the communications; this soon became very violent and was accompanied by discharges of grape from all parts of the works. Six rounds were fired from the guns between Nos. IV and V, nine from those between III and IV, five from those between I and IV. Some guns in redoubts Nos. II, IV, VI, and VIII managed to open fire before they were carried. Wall-pieces were also largely used.

The enemy's musketry was more fatal than his grape, though nothing was able to check the irresistible charge and good order of our columns. The communication on the right of No. III, attacked both front and rear, was carried first, 15 minutes after the troops had left the 3rd parallel. Almost at the same

* It seems a mistake to speak of the *proximity* of a 3rd parallel 400 yds. from the works attacked. Had the Danes been able to maintain any front of fire, this distance would have afforded them time to have well nigh exterminated the columns of assault.—ED.


PLAN
of the Attack on the
DÜPPEL ENTRENCHMENTS.
March & April, 1864.
Explanation.
The Danish Works are shown thus
The Prussian Works
SONDERBURG
Baudsager Batt?
Kirkberg Batt?
Sondermühlen Batt?
Baudsager
Castle
ALSEN
ALSEN SUND
Flanken Batt?
Sartykers Batt?
Boom
Sarlyk
Steingaard
Sneg
ENCAMPMENT
Horlyk
Düppel Mill
abgebr
WENNING BUND
Lille Molle
Rand - sand
Batrup
Stabe - gaard
Oster Düppel
Stridspot
12_18 April, III Parallel.
10_11 April, II Parallel.
7_8 April, Demi-Parallel.
29_30 March, I Parallel.
Rackebüll Holz
Rackebüll
Düppel
Lye
Kirch Düppel
Freudenthal
Gammelmark
Sønderup Moor
Willersholm
Krug
Wester Düppel (Wiethal)
Düppelfeld
Stenderup
Stenderuper
Holz
Steinbek
Wenning
Dünth
Bufjel Koppel
Wenningwedt
Scale.
1000 500 0 1000 2000 English Yards
1/10.000
Kell Bros Lith. Castle St. Holborn.

time Nos. I, V, and VI fell. In No. II the struggle was of somewhat longer duration.

No. IV, occupying the most re-entering position of the whole line, held out the longest. The column of assault told off for it was the only one which, received by grape in front and flank, could not attain its object by a direct advance, and was obliged to turn No. III in order to take it. Notwithstanding this the Prussian flag was flying on No. IV at 22 minutes past 10.

The columns of assault being thus in possession of the whole line from the Wenningbund to No. VI, an advance was immediately made, particularly from the trenches of communication. The 2nd or retired line which the Danish reserves ought to have occupied at the moment of the assault, but which they had not even now reached, was taken, and the enemy pursued beyond it.

Near No. IV the pursuit took an oblique direction towards the Düppel mill, which, being carried, our troops advanced straight on the bridge-head. It is stated in the Danish report that we had arrived about half-way between lunettes A and B and the bridge-head, when the Danish reserves were put in motion to stop us. The encounter that now took place had lasted about half an hour, and our troops, numerically much weaker, were being forced back, when our reserves came up and decided the issue of the engagement. We immediately assumed the offensive and drove back the Danes with considerable loss into the bridge-head. This was about noon, and from this hour the defence was restricted to the possession of this work and of Alsen. It was in the encounter just referred to that the value of the needle-musket was incontestably proved, for without it we could never have held our ground as we did against the enemy's far superior numbers.

About 11 o'clock the two reserve companies of the column of assault for No. VI attacked No. VII by the gorge and carried it; shortly after No. VIII was also attacked by the gorge; but as works VII to X had not been destroyed by our fire to the same extent as I to VI, the difficulties in the way of assault were much greater. Thus the first attack on No. VIII failed, and it had to be repeated from the side of No. VI, when the garrison was made prisoners.

Soon after this the Danes were ordered to retreat from Nos. IX and X on the bridge-head to avoid their being cut off. Before, however, the garrison of No. IX could obey this order, the work was attacked both in front and flank, carried after a sanguinary fight and the garrison made prisoners.

Thus of the ten works forming the Düppel position, nine, and the 2nd line of works, had been carried by assault.

The enemy suffered considerable loss in retreating on the bridge-head, into which all his remaining troops had been withdrawn shortly after noon.

The defences of this work being still perfect, the idea could not be entertained of carrying it by assault, it moreover being closely flanked and its interior commanded by the enemy's batteries and reserves on the opposite bank of the Alsen Sund. A combat of artillery and musketry was maintained for about an hour, when the enemy came to the determination of abandoning the bridge-head, and broke up first the north bridge and then the south one, it being exactly half-past one when his retreat was finally effected.

The Danish loss on the day of assault is put down at 110 officers (among them General Du Plat) and 4,736 men; our own loss was 70 officers (among them General von Raven) and 1,118 men.

PAPER XIV.

NOTES ON THE DEFENCES OF PETERSBURG.

By LIEUT. FEATHERSTONHAUGH, R.E.

The following notes were made during a visit to Richmond and Petersburg, in the month of November, 1864. They are written now entirely from memory, the route by which I left the Confederate States not permitting me to take any description whatever, on paper, of the defence of Petersburg, then besieged by the Federal army.

The Confederate position extended from the Chickahominy River down to the James at Chapin's Bluff, which is almost opposite Fort Drury or Darling, being about 200 yds. lower down the stream. From Fort Drury the line passed down to Howlett's Battery, on the high ground commanding Dutch Gap, and from thence nearly due south to Petersburg, crossing the Apomattox a little to the north-east of the town. From the south side of this river the defences ran nearly south-west towards the Weldon Railroad, where they died out, neither army extending its flank beyond the railway, which was, however, cut by the Federals.

The works of attack of General Grant ran parallel to the Confederate lines, resting on the James on its northern side at Ball's Bluff, and occupying the double-headed peninsula between Dutch Gap on the James and the Apomattox. To the south of the latter they continued parallel to the Confederate works.

Various statements appeared in the newspapers, both in the United States and in England, during the autumn of 1864, about the great strength of the Confederate lines and their impregnable nature. These accounts were much exaggerated; the works on the north side of the James were certainly strong if defended by adequate forces; but the lines in front of Petersburg, and to the south-west of it, which formed the right of the Confederate position, were by no means formidable, either in trace or in profile. The general disposition was as follows: the line followed for about a mile and a half a ridge which ran past the town at a distance of a quarter of a mile from east to south-west; at intervals of 200 or 300 yards or more, according to the ground, were batteries thrown forward as salients, and traced either as small bastions, demi-bastions, or lunettes; these were united by a line of parapet running from the flank of one to that of the next. These batteries therefore were the vital points of the line, and in the construction of them lay the great difference in strength of the line to the north of the James from that to the south of it. The batteries on the north side of the river were amplified into forts having ditches and palisaded gorges, whilst those on the south side had neither one nor the other.

When the Federals crossed the James, about the middle of June, 1864, after the battles of the Wilderness, Spottsylvania, and White House, and attacked Petersburg, the Confederates only arrived in time to save the town, and the defences on the south-east side were partly captured; in consequence they threw up a breastwork in rear of their former position, which they held until reinforcements arrived, but they never succeeded in retaking that part of their original line. The breastwork thus formed was thrown up from the inside, the profile was that of a first parallel, the trench inside being in some places very narrow indeed. The parapets of the batteries were of course thicker than those of the lines between them, but there were no ditches in part of them as stated above. A row of chevaux-de-frise was placed in front of the line, and in some places there were two rows; in front of all, at varying distances, were the rifle-pits containing the piquets. The batteries gave each other good flanking fire, and the whole of the ground in front was no doubt well commanded, but the defences were not of a character, nor were they intended to be so, to enable a small force to defend itself against a much larger one. The so-called siege of Petersburg was really the siege of Richmond conducted at a distance of 20 miles against an army which had retrenched itself and occupied a position 25 miles in length as the crow flies. The triple line of entrenchments sometimes alluded to in the accounts published at the time may perhaps be explained by the fact that in many places the rifle-pits of the piquets were connected by a low parapet which enabled the reliefs to be made in safety, which could not otherwise have been done where the enemy's posts were very close. This may be therefore called the "first line." The "second line" was the real one, and the "third line" was probably a parapet about half a mile long, which was in rear of one part of the defences and which had been left half finished. It was not revetted, there were no troops encamped in rear of it, and it did not appear capable of being of any assistance in the event of the main line being carried or penetrated. It was intended during the winter to throw up redoubts in rear of the position, mounted with artillery, to serve as keeps to the whole defences, but there were none at all there in November, that is to say, on the south side of the James River.

The batteries mentioned above were armed with field-guns, chiefly brass "Napoleons" and small columbiads, most of the latter having the letters U.S. marked on them; the former came from the Richmond foundries. The parapets were thick and the faces carefully traversed, some of the pieces had shields for protection against rifle shots made of three thicknesses of plank nailed together, and fitted over the breech just in front of the sight, a slit being cut in the shield to enable the gun to be laid. With breech-loading guns this sort of shield would give very efficient protection against riflemen. The revetments were almost uniformly of logs of pine of 12 or 14 inches girth, laid horizontally and parallel to the crest of the parapet. The mode of working was as follows: a line of logs, as described, was laid in the direction of the revetment intended to be built, stakes about 3 feet long were then laid across them at right angles to their length, the head of each stake appearing on the face of the revetment, and lapping over the log beneath it by a notch cut for the purpose. The earth being then filled up behind and between the timber, another row of logs was added, then another of stakes, and so on alternately, headers and stretchers until the work was finished. The appearance of this kind of revetment was exceedingly neat, and I was told it was very durable. It can of course be only used where timber of the requisite size can be obtained in abundance, such as is the case in Virginia, which is covered with small second-growth pine, whose branches are very unfit for making gabions and fascines, but whose stems grow straight and taper gradually, furnishing logs of the size described.

The chevaux-de-frise were simply constructed of square logs with holes, through which the spikes were passed; the lengths were generally lashed together, and a double row was set up, as before stated, in some places. Small covered-ways starting from tunnels under the parapet gave access to the line of rifle-pits which was sometimes only 25 or 30 yds. distant. Where the Federal piquets were close, and the sharpshooting constant, there were also covered-ways from the rear to the main line. Immediately in front of Petersburg, where the hostile piquets were very close to one another, the rifle-firing was continual, both day and night; this was purposely kept up by the Confederates to ensure the vigilance of their sentries. Where the distance of the piquets was greater, there was, as a rule, no sharpshooting. The men used large logs of wood which they laid along the top of the parapet or rifle-pit, as the case might be, and out of the under side of which a small loop-hole was cut; this enabled them to keep up a sharp fire without many of them being hit.

One of the principal salients immediately in front of the town was Colquest's Salient; it was under this that the Federals exploded their large mine on the 30th of July, which made a breach through which they nearly penetrated.

During the 29th, General Grant moved large numbers of his troops and, to add to the deception, of empty baggage waggons, from the south to the north side of the James River. General Lee, to oppose this movement, took a large force also over to the north side of the river, but suspecting something, he left word on the south side to be especially watchful. During the night of the 29th the Federal troops were brought hastily back again, and the mine was sprung at day-break of the 30th, the Confederate troops who had crossed the river not having returned.

The mine was, as far as it went, completely successful; the gallery leading to it was, it was said, 300 yds. long,* it was 30 feet below the parapet, and its existence was not suspected by the Confederates, or if it was, they had no information precise enough to enable them to guard against the danger. The crater made by the explosion was very large, a length of 200 feet of parapet were destroyed, and a long gap made in the line, the troops on the spot being either killed or buried alive by the earth. The next part of the assault was not so successful. Coloured troops had been selected to penetrate into the gap, which they did with a rush, capturing the piquet line and filling the crater; here, however, they were checked, first, by the side of the crater, which, even when I saw it, after it had been partially filled up, was 8 or 10 feet deep, and, secondly, by the artillery fire, which the batteries on either flank had by this time opened upon them. The Southern troops to the right and left of the gap behaved with great steadiness, they formed hastily behind the mounds of earth thrown up by

* This distance is probably too much, but there is no doubt that the mining was very skilfully done.

the explosion, and drove back into the crater those of the enemy who had penetrated beyond it. Fresh efforts were made by the Federals to advance still further, but without success; the men who had made the first assault were all hemmed in in the crater, unable to advance or retire, and they blocked up by their presence the way through which fresh troops might have advanced to the attack. Eventually, after great losses, the Federal troops in the crater surrendered, and a truce was made for a few hours to bury the dead. The loss of the Northern army on this occasion was large; it was stated at 5,000 men, casualties and prisoners, but this is probably an exaggeration.

The reason I heard most frequently given for the failure of the assault was the employment of coloured troops in the first attack instead of white regiments; it is no disparagement to the former to say that the latter would have done better, if only for the reason that they were more experienced.

The crater was in November 50 yds. long by 30 wide, measured inside the perpendicular walls of earth which formed its sides; the depth was then, as before stated, from 8 to 10 feet. The salient which had been destroyed was reconstructed immediately in rear of its former position, and the strength of the line was not materially injured by the alteration.

One of the principal features of the works was the extensive use made of bombproofs; owing to the great length of the lines, the same troops were constantly kept in the trenches, and it was necessary to give them ample protection from the weather and from the Federal bombardments. The bombproofs were long trenches cut in the ground just behind the parapets and parallel to them; the sides of the trenches were lined with rough slabs of fir, the roof was supported by uprights at sufficient intervals, carrying plates on which were laid the cross-pieces over which the earth was heaped to the depth required. The cross-pieces were generally small trees sawn into two pieces longitudinally, and the sawn side being laid downwards bore evenly upon the plates, and at the same time gave a tolerably smooth appearance to the ceiling. The cross-pieces were laid close to each other, both for strength and to prevent the earth from crumbling and falling through. Fire-places and chimneys were constructed in these bombproofs, and they looked and were much more comfortable than would have been imagined. According to the shape of the ground and the site, the bombproofs were what may be called sunken, half-sunken, or elevated, in the latter case the top was sometimes used as a cavalier. In one or two places the very parapet of the main line was used as a bombproof.

A countermine was constructed after the attack of the 30th of July mentioned above, in order to detect any future attempts of the same nature. This countermine had many branches radiating from the advanced point of the main gallery which extended about 50 yards in front of the parapet. Frames and sheeting were the lining used, the work was very neatly done, and the interior of the mine was dry and well ventilated. Small holes had been made in the floor of the galleries, and filled with water to show if any excavation was going on below them, but it is doubtful whether they would have answered the purpose, as the soil appeared to have too much clay in it to allow penetration through even a few feet.

Between Colquest's salient, mentioned above, and the next one on its left called Gracie's salient, was a ravine whose direction was at right angles to the line of defences, and through which a stream of water ran to join the Apomattox River. Across the ravine a dam was made with a parapet along the top, and with sluice gates at each end, so that the stream, which was not large, ran through as before. A little higher up the stream, but out of sight of the dam, was the piquet line of the Federals, and some considerable portion of it was on some rising ground between the stream and the Confederate works. One night, after much rain, when the stream was very full, the sluice gates were shut, and the water accumulating, flooded the ground between the Federal piquet line and their own works. At day-break the Confederates attacked the piquet line, and in the confusion created by the new state of things, succeeded in breaking it up and capturing a large number of prisoners. After this the ground was not again occupied by the Federal piquets, and the defence of that portion of the lines was rendered much easier.

The soil was everywhere of a very favourable nature for earthworks, being the red loamy clay which occurs all along the eastern parts of Maryland and Virginia; it is easily dug and stands well when formed into slopes.

The defences on the north side of the James River were, as I have said, stronger than those on the south side. The system was the same, but the batteries were more roomy and were enclosed in rear by palisades so as to form redoubts. There were also ditches in front of the parapets, and more obstacles in the shape of abattis and chevaux-de-frise than on the other line. Just outside the parapet, at the foot of the exterior slope, was a line of live shells at intervals of a yard, just buried in the earth, each with a very sensitive percussion fuze; a small red flag marked the place of each shell.

There were two more lines of defences of a similar character between Richmond and Petersburg, intended, I presume, for the Confederate army to fall back upon if the first one was forced. But the position at Petersburg was the important one, as any line nearer to Richmond would not have enabled the Confederate General to keep his communication with the interior sufficiently open. In fact, General Lee, to the last, clung to the position he had occupied so long, and when he left it it was to try and escape into the interior, not, as it appears, to endeavour to entrench himself round Richmond.

The Federal attacking works were, I have been told, very skilfully constructed; I had never any opportunity of seeing them close. They were, however, strong, both for offence and defence, and as their army was supplied by water carriage and by a railway up to within range almost of the Confederates' fire, it is probable that no materials or skilled labour were wanting. With the Confederates it was very different, and considering the scarcity of everything which prevailed, their works were, as far as I could judge, most skilfully constructed.

A. F.

Bermuda.

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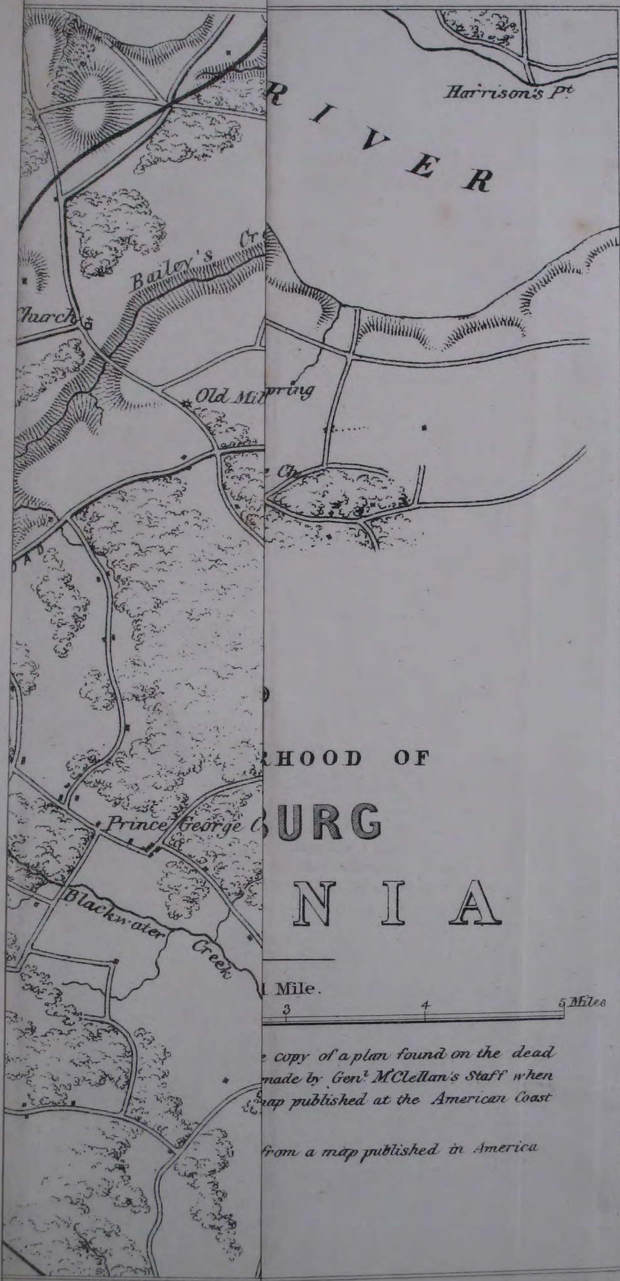
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